

Service Manual

B3.3 Diesel Engine

D20S-5, D25S-5, D30S-5, D33S-5, D35C-5

D20S-3, D25S-3, D30S-3, D32S-3, D33S-3

D20G, D25G, D30G

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the "Safety" section or the Service or Technical Manual. Additional safety precautions are listed in the "Safety" section of the owner/operation/maintenance publication. Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product.

Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

Index

Introduction

About the Manual.....	5
How to Use the Manual.....	5
Symbols	6
Illustrations.....	7

Engine Identification

Engine Identification.....	8
Engine Datplate	8
Specifications	9
Engine Diagrams	10
Engine Views	10

Troubleshooting Symptoms

Troubleshooting Symptoms	21
Procedures and Techniques	21
Troubleshooting Symptoms Charts.....	21
Engine Acceleration or Response Poor.....	22
Engine Acceleration or Response Poor (Continued)	
.....	23
Engine Will Not Crank or Cranks Slowly.....	24
Engine Will Not Crank or Cranks Slowly (Continued)	
.....	25
Engine Cranks But Will Not Start	
(No Exhaust Smoke).....	26
Engine Difficult to Start or Will Not Start	
(Exhaust Smoke)	27
Engine Difficult to Start or Will Not Start	
(Exhaust Smoke) (Continued)	28
Engine Has Poor Responses	29
Engine Stops During Operation	30
Engine Runs Rough or Misfires	31
Engine Power Output Low	32
Engine Power Output Low (Continued)	33
Excessive Exhaust (Black Smoke)	34
Excessive Exhaust (White Smoke).....	35
Lubricating Oil Consumption Excessive	36
Lubricating Oil Contaminated	37
Fuel consumption Is Excessive	38
Coolant Contamination	39
Coolant Loss.....	40
Lubricating Oil Pressure Is Low	41
Oil Level Rises.....	42
Coolant Temperature above Normal	43
Excessive Noise	44

Excessive Noise (Continued)	45
Engine Vibration Excessive	46

Complete Engine

Complete Engine	47
Engine Disassembly	47
Engine Assembly.....	66

Engine System

Engine System.....	95
Bearing, Connecting Rod	95
Bearing, Main	100
Bearing, Thrust.....	105
Camshaft	107
Camshaft Bushings	110
Camshaft Gear	112
Connecting Rod.....	113
Crankshaft	120
Crankshaft Gear, Front.....	125
Crankshaft Pulley	126
Crankshaft Seal, Front.....	128
Crankshaft Seal, Rear	129
Cylinder Block.....	130
Gear Cover, Front.....	134
Idle Gear, Camshaft	136
Piston.....	139
Piston Rings	142
Piston and Connecting Rod Assembly	146
Gear Train Backlash, Front	156
Camshaft Thrust Bearing.....	157
Cylinder Head.....	158
Rocker Levers.....	164
Adjusting Valve Clearance	164
Rocker Levers Assembly	166
Rocker Lever Cover.....	169
Push Rods or Tubes	170
Tappet.....	171
Complete Engine	173
Measuring Compression Pressure	173
Testing and Adjusting the Fan Belt Tension.....	175
Fuel System.....	176
Fuel Injection Pump, Rotary	176
Injector	181
Testing	181
Lubricating System	186
Measuring Oil Pressure	186
Lubricating Oil Cooler (If equipped).....	186
Lubricating Oil Pressure Regulator (Main Rifle) .	188

Lubricating Oil Suction Tube (Block-Mounted) ...	191
Cooling System.....	192
Coolant Thermostat	194
Coolant Thermostat Housing	195
Cooling System.....	196
Cooling System Diagnostics	199
Engine Compression.....	205

Specifications

Specifications	208
Valves, Valve Guides, and Springs	208
Rocker Arm Shaft, Push Rod and Tappets.....	209
Cylinder Head	210
Cylinder Block.....	211
Camshaft and Camshaft Bushing.....	212
Crankshaft	213
Timing Gear	214
Flywheel.....	215
Cylinder.....	216
Piston.....	217
Connecting Rod, Piston Ring and Piston Pin	218
Oil Pump	219
Regulator Valve	220
Thermostat.....	221
Capscrew Markings and Torque Values.....	222
Capscrew Markings and Torque Values - Metric	222
Capscrew Markings and Torque Values - U.S.	
Customary	223
Fraction, Decimal, Millimeter Conversions	224
Newton-Meter to Foot-Pound Conversion Chart	225
Pipe Plug Torque Values	225
Tap-Drill Chart - U.S. Customary and Metric.....	226
Weight and Measures - Conversion Factors	227

Special Tools

Special Tools	228
---------------------	-----

About the Manual

This Troubleshooting and Repair Manual is intended to aid in determining the cause of engine-related problems and to provide recommended repair procedures.

The material in this manual covers all Signature engines. The manual is divided into sections. Each section is equivalent to a group used in Cummins filmcards system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. Procedure numbers are used to identify and reference specific repair **procedures** for correcting the problem.

This manual is designed so the troubleshooting trees are used to locate the cause of an engine problem. The troubleshooting trees then direct the user to the correct repair procedure. The repair procedures within a section are in numerical order. However, the repair steps within a given procedure are organized in the order the repair must be performed, regardless of the numerical order of the steps. The user **must** use the Section Contents pages or the Index at the back of the manual to locate specific topics when **not** using the troubleshooting trees.

How to Use the Manual

This manual is organized to provide an easy flow from problem identification to problem correction. A list of troubleshooting symptoms containing the most common engine problems is in the Troubleshooting Symptoms, Section TS. The manual is designed to use the Troubleshooting Symptoms as a guide to locating the problem and directing the end user to the correct procedure for making the repair. Complete the following steps to locate and correct the problem.

- (Step 1) Locate the symptom on the Section Contents pages of Section TS. Reference to the page number where the Troubleshooting Symptom Tree is found is made to the right of the symptom tree title.
- (Step 2) The left column of boxes in the Troubleshooting Symptom Charts indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult. The right column of boxes provides a brief description of the corrective action with a reference number to the correct procedure used to make the repair.
- (Step 3) Locate the probable cause in the left column; then turn to the procedure referenced in the right column.
- (Step 4) The Troubleshooting Symptom Charts are based on the following assumptions:
 - 1. The engine has been installed according to the manufacturer's specifications.
 - 2. The easiest repairs are done first.
 - 3. "Generic" solutions cover problems with the most common applications and original equipment manufacturer (OEM).

Symbols

The following symbols have been used in this manual to help communicate the intent of the instructions. When one of the symbols appears, it conveys the meaning defined below:



WARNING – Serious personal injury or extensive property damage can result if the warning instructions are not followed.



CAUTION – Minor personal injury can result or a part, an assembly or the engine can be damaged if the Caution instructions are not followed.



Indicates a **REMOVAL** or **DISASSEMBLY** step.



Indicates an **INSTALLATION** or **ASSEMBLY** step.



INSPECTION is required.



CLEAN the part or assembly.



PERFORM a mechanical or time **MEASUREMENT**.



LUBRICATE the part or assembly.



Indicates that a **WRENCH** or **TOOL SIZE** will be given.



TIGHTEN to a specific torque



PERFORM an electrical **MEASUREMENT**.



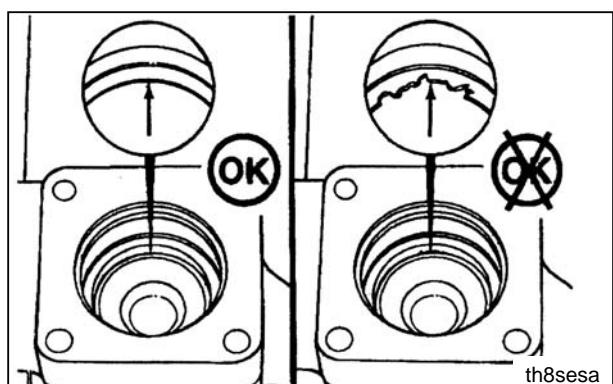
Refer to another location in this manual or another publication for additional information.



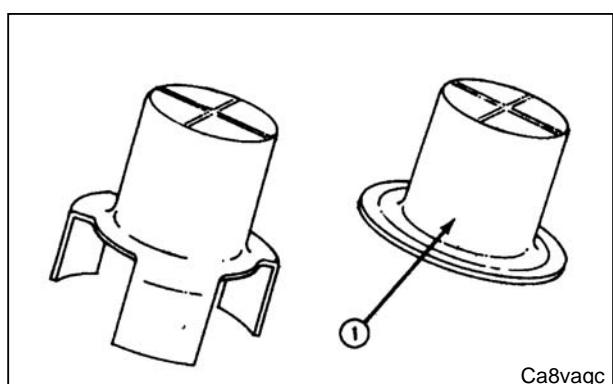
The component weighs 23kg [50lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Illustrations

Some of the illustrations throughout this manual are generic and will **not** look exactly like the engine or parts used in your application. The illustrations can contain symbols to indicate an action required and an acceptable or **not** acceptable condition.



The illustrations are intended to show repair or replacement procedures. The procedure will be the same for all applications, although the illustration can differ.

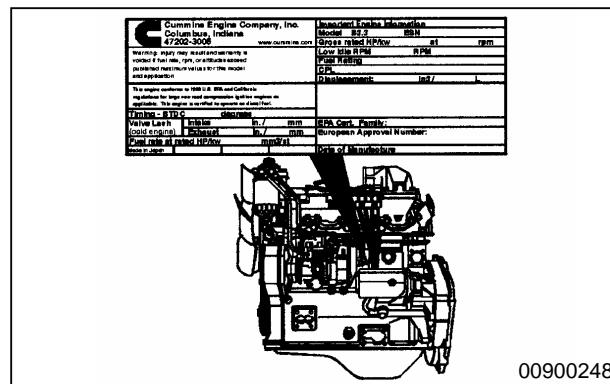


Engine Identification

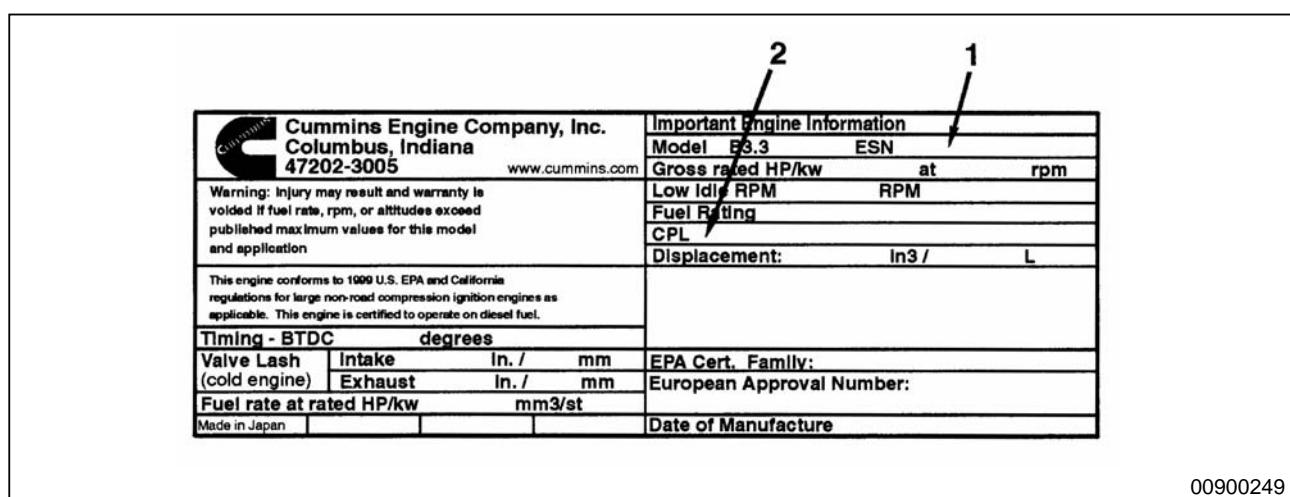
Engine Dataplate

The engine dataplate shows specific information about the engine. The engine serial number (ESN) and control parts list (CPL) provide information for ordering parts and for service needs.

NOTE: The engine dataplate **must not** be changed unless approved by Cummins Engine Company, Inc.



00900248



00900249

Specifications

Performance			All Models
Rated Power		kW(PS)	43.4 (59) @ 2,200 rpm
Max Torque		Nm(kgf-m)	202 (20.6) @ 1,600 rpm
Torque Rising			7.4% for 2,200 rpm rating
BSFC	@ Rated Power	g/kWh	227 @ 2,200 rpm
	@ Max Torque	g/kWh	219 @ 1,600 rpm
Low Idle rpm	@ Dynamo	rpm	2,500 ±25
	@ Truck	rpm	2,470 ±50
High Idle rpm	@ Dynamo	rpm	800 ±25
	@ Truck	rpm	770 ±25
General Engine Data			Naturally Aspirated
Engine Weight (Dry) Less Flywheel and Electronics			245 kg [540 lb]
Compression Ratio			18.8
Bore			95 mm [3.74 in]
Stroke			115 mm [4.528 in]
Displacement			3.26 liters [199 in ³]
Firing Order			1-2-4-3
Valve Clearance:	Intake		0.35 mm [0.014 in]
	Exhaust		0.50 mm [0.020 in]
Rotation Viewed from the Front of the Engine			Clockwise
Lubrication System			Naturally Aspirated
Regulating Valve Opening Pressure			490 kPa [71 psi]
Lubricating Oil Capacity:	Total System Standard Oil Pan Only		7.5 liters [8.0 qt] 7.0 liters [7.4 qt]
Lubricating Oil Pressure at Idle (Minimum Allowable)			69 kPa [10 psi]
Lubricating Oil Pressure at Rated (Minimum Allowable)			245 kPa [35 psi]
Oil Filter Differential Pressure to Open Bypass Valve			98 kPa [14 psi]
Number of liters [qt] from Low to High			1.5 liters [1.6 qt]
Cooling System			Naturally Aspirated
Coolant Capacity (Engine Only)			4.5 liters [4.75 qt]
Standard Modulating Thermostat Range:	Start Fully Open		82° C [180° F] 95° C [203° F]
Maximum Pressure Cap @ Sea Level			50 kPa [7 psi]
Air Induction System			Naturally Aspirated
Maximum Allowable Intake Restriction at Rated Speed and Load with Dirty Filter Element			762 mm H ₂ O [30 in H ₂ O]
Exhaust System			Naturally Aspirated
Maximum Allowable Exhaust Restriction at Rated Speed and Load with Dirty Filter Element			75 mm Hg [3 in Hg]
Fuel System			Naturally Aspirated
Maximum Allowable Restriction to the Fuel Transfer Pump or Filter Head Must Not Exceed			75 mm Hg [3 in Hg]
Maximum Allowable Return Line Restriction Must Not Exceed			190.5 mm Hg [7.5 in Hg]
Inlet Pressure to the Injection Pump Range			0.00 kPa [0.00 psi] to 39.0 kPa [5.00 psi]
Electrical System			Naturally Aspirated
Minimum Recommended Battery Capacity with Light Accessories*:	12-VDC Starter		550 CCA
Minimum Recommended Battery Capacity with Heavy Accessories**:	12-VDC Starter		730 CCA
Maximum Allowable Resistance of the Starting Circuit:	12-VDC Starter		0.0012 ohms

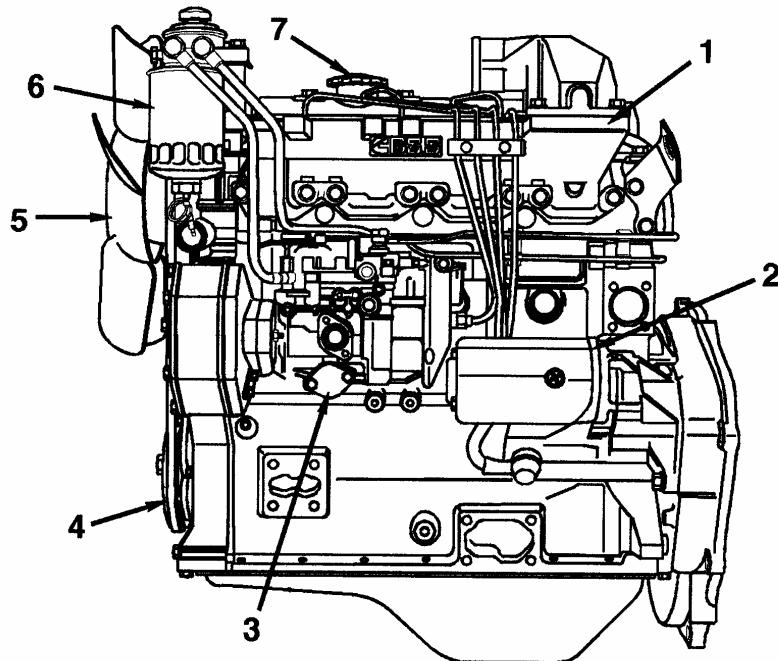
*Typical light accessories include: Alternator, small steering pump, and disengaged clutch.

**Typical heavy accessories include: Hydraulic pump and torque converter.

Engine Diagrams

Engine Views

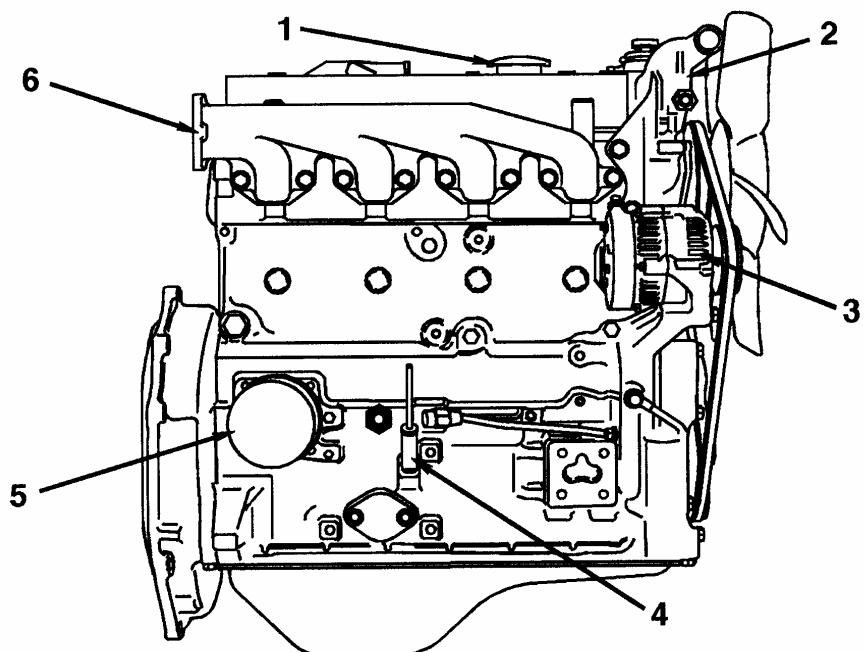
The following illustrations show the locations of the major external engine components, filters, and other service and maintenance points. Some external components will be at different locations for different engine models.



**Intake Side
(Naturally Aspirated)**

00900138

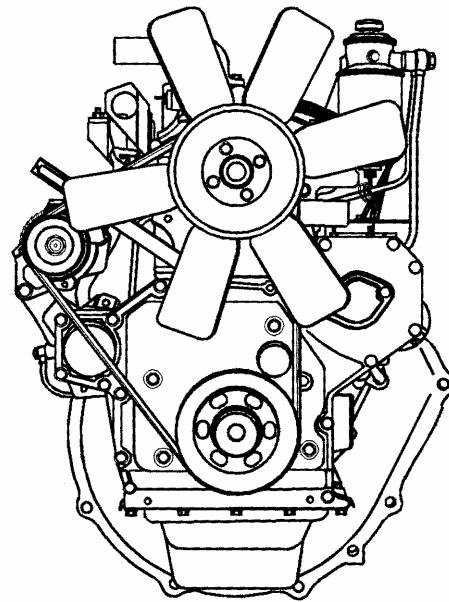
1. Intake Manifold	5. Fan
2. Starting Motor	6. Fuel Filter
3. Fuel Injection Pump	7. Oil Fill Cap.
4. Crankshaft Pulley	



**Exhaust Side
(Naturally Aspirated)**

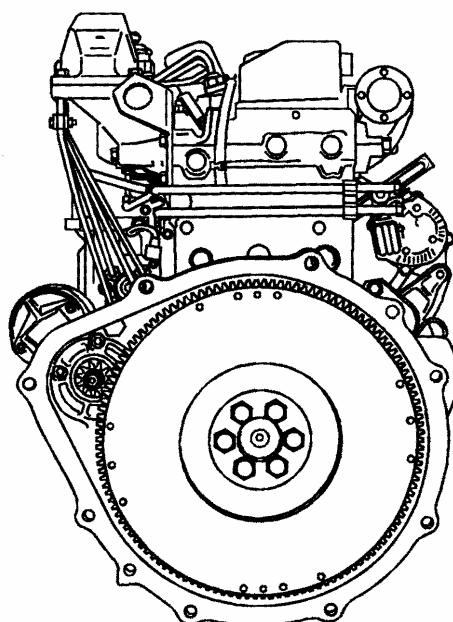
00900139

1. Oil Fill Cap	4. Dipstick
2. Thermostat Housing	5. Oil Filter
3. Alternator	6. Exhaust Manifold.



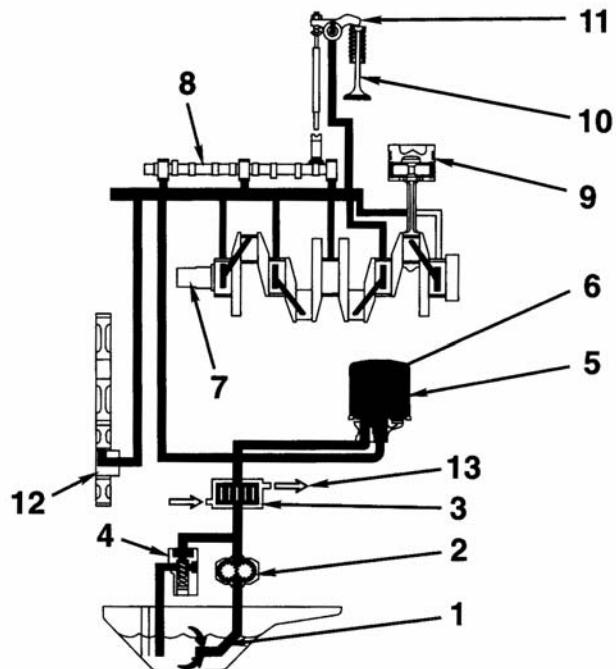
Front View
(Naturally Aspirated)

00900140



Rear View
(Naturally Aspirated)

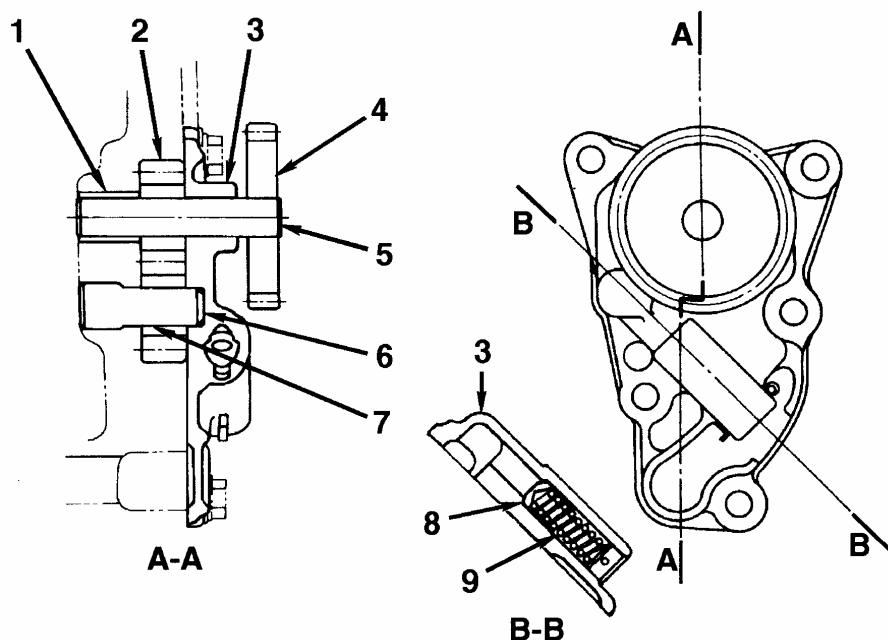
00900141



**Exhaust Side
(Naturally Aspirated)**

00900146

1. Oil Strainer	8. Camshaft
2. Oil Pump	9. Piston
3. Oil Cooler (Optional)	10. Intake and Exhaust Valve
4. Regulator Valve	11. Rocker Arm
5. Oil Filter	12. Timing Gear
6. Safety Valve	13. Cooling Water.
7. Crankshaft	



Oil Pump

00900148

1. Bushing
2. Gear Drive (number of teeth: 7)
3. Pump cover
4. Oil Pump Drive Gear (number of teeth: 22)
5. Driveshaft
6. Driveshaft
7. Driven Gear (number of teeth: 7)

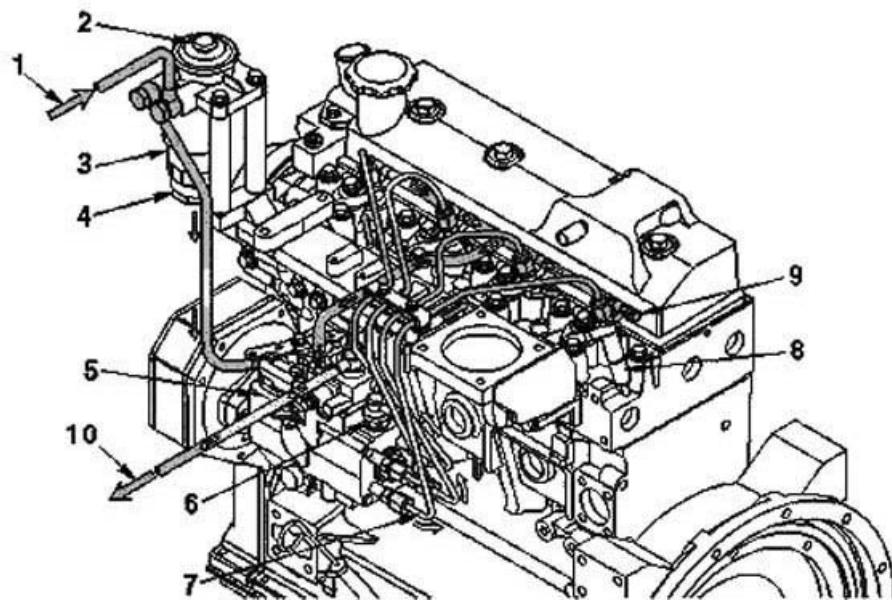
8. Regulator Valve
9. Valve Spring.

Oil pump

- Type: Gear Type
- Gear drive number of teeth (7)
- Oil pump drive gear number of teeth (22)
- Driven gear number of teeth (7)
- Pump Speed: Engine Speed x 1.182.

Regulator Valve

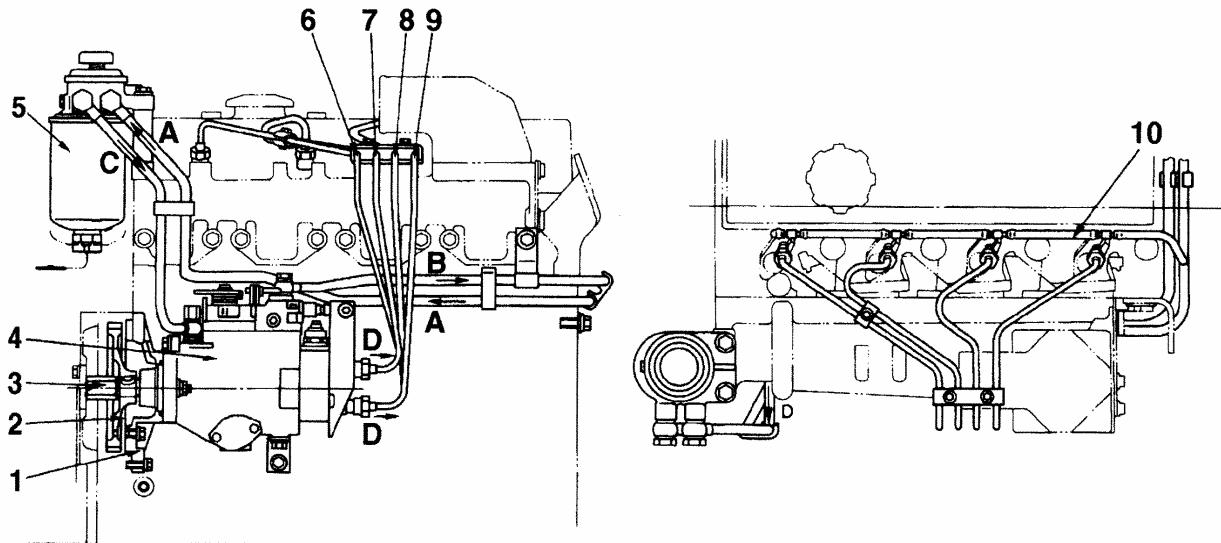
- Set Pressure: $490 \pm 50\text{kPa}$ [$71 \pm 7\text{psi}$].



Fuel System

05900870

1. Fuel supply from tank	6. Fuel shutoff solenoid
2. Hand priming pump	7. High-pressure fuel line
3. Fuel filter	8. Injector
4. Water in fuel sensor	9. Fuel drain manifold
5. Fuel pump	10. Fuel return to tank.



Fuel Injection Pump

00900150

1. Pump Holder
2. Fuel Injection Pump Drive Gear
(number of teeth: 52)
3. Drive Shaft
4. Fuel Injection Pump (Body)
5. Fuel Filter
6. Fuel Injection Pipe (No. 1)
7. Fuel Injection Pipe (No. 2)
8. Fuel Injection Pipe (No. 3)
9. Fuel Injection Pipe (No. 4)
10. Spill Tube

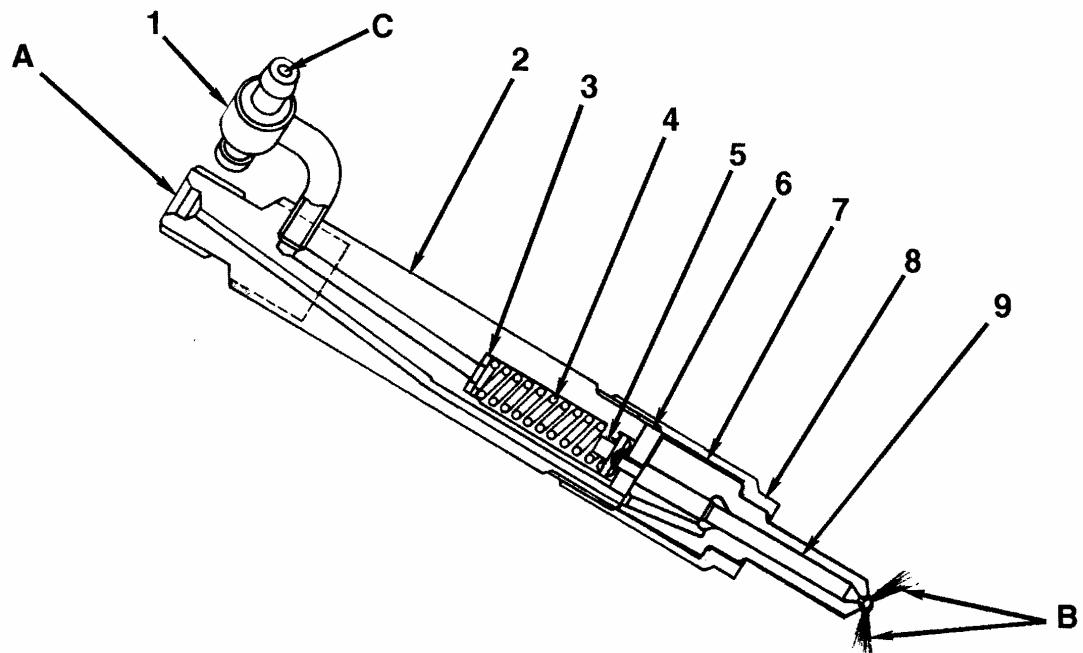
- A. Fuel Inlet (from Fuel Tank)
- B. To. Fuel Tank
- C. To Fuel Injection Pump
- D. To Fuel Injection Nozzle.

Fuel Injection Pump

- Maker: Zexel
- Type: VE
- Lubrication Method: Forced Lubrication with Fuel

Governor

- Type: Mechanical, All-speed Type.



Fuel Injection Nozzle

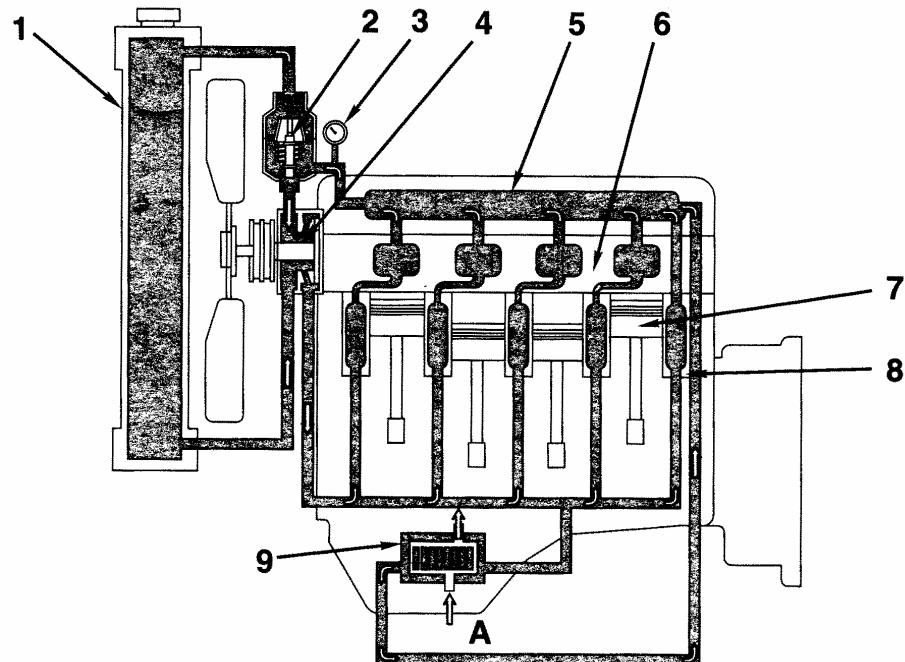
00900151

1. Fuel Drain Line Connector
2. Nozzle Holder
3. Adjusting Shim
4. Nozzle spring
5. Spring seat
6. Intermediate Plate
7. Nozzle Body
8. Retaining Nut
9. Needle.

- A. Fuel Inlet (from injection pump)
- B. Fuel Injection (to cylinder)
- C. Fuel Return (to fuel tank).

Fuel Injection Nozzle

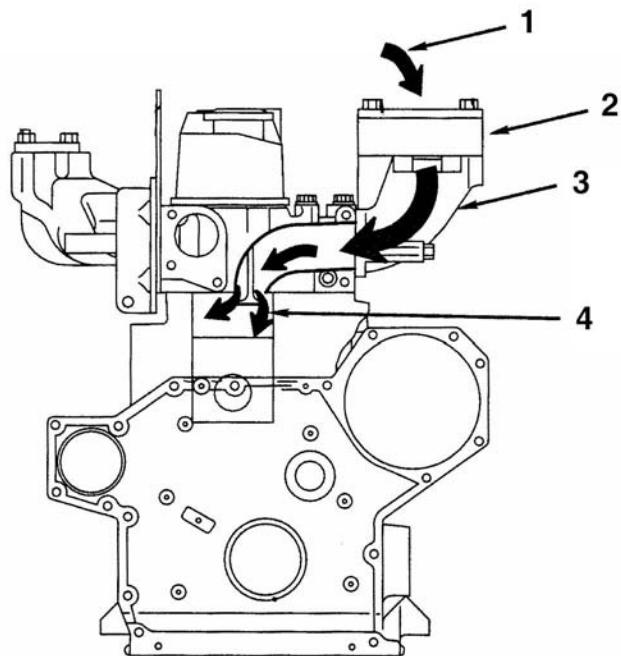
- Maker: Zexel
- Injection Pressure: 40 MPa
- Adjustment of Injection Pressure: By Shim.



Cooling System

00900147

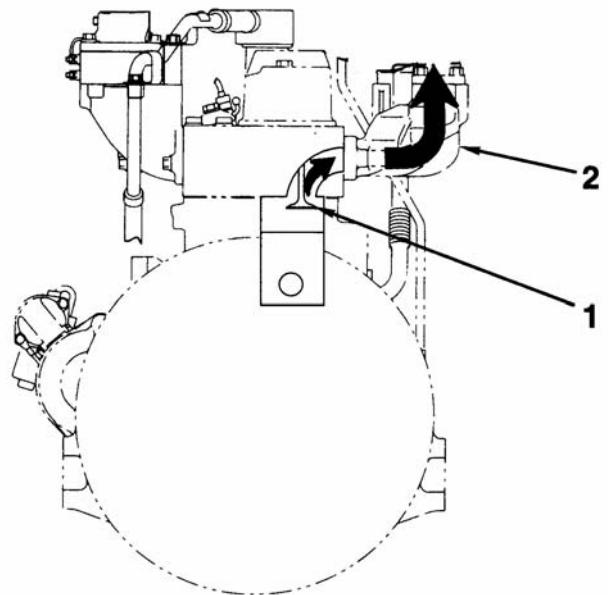
1. Radiator	6. Cylinder Head
2. Thermostat	7. Piston
3. Water Temperature Gauge	8. Cylinder Block
4. Water Pump	9. Oil Cooler (optional).
5. Water Manifold	A. From Oil Pump (oil).



Air Intake System

00900227

1. Filtered Air
2. Air Heater
3. Intake Manifold
4. Intake Valve Port.



Exhaust System

00900232

1. Exhaust Valve Port
2. Exhaust Manifold

Troubleshooting Symptoms Procedures and Techniques

A thorough analysis of the customer's complaint is the key to successful troubleshooting. The more information known about a complaint, the faster and easier the problem can be solved.

The Troubleshooting Symptom Charts are organized so that a problem can be located and corrected by doing the easiest and most logical things first. Complete all steps in the sequence shown from top to bottom.

It is **not** possible to include all the solutions to problems that can occur; however, these charts are designed to stimulate a thought process that will lead to the cause and correction of the problem.

Follow these basic troubleshooting steps:

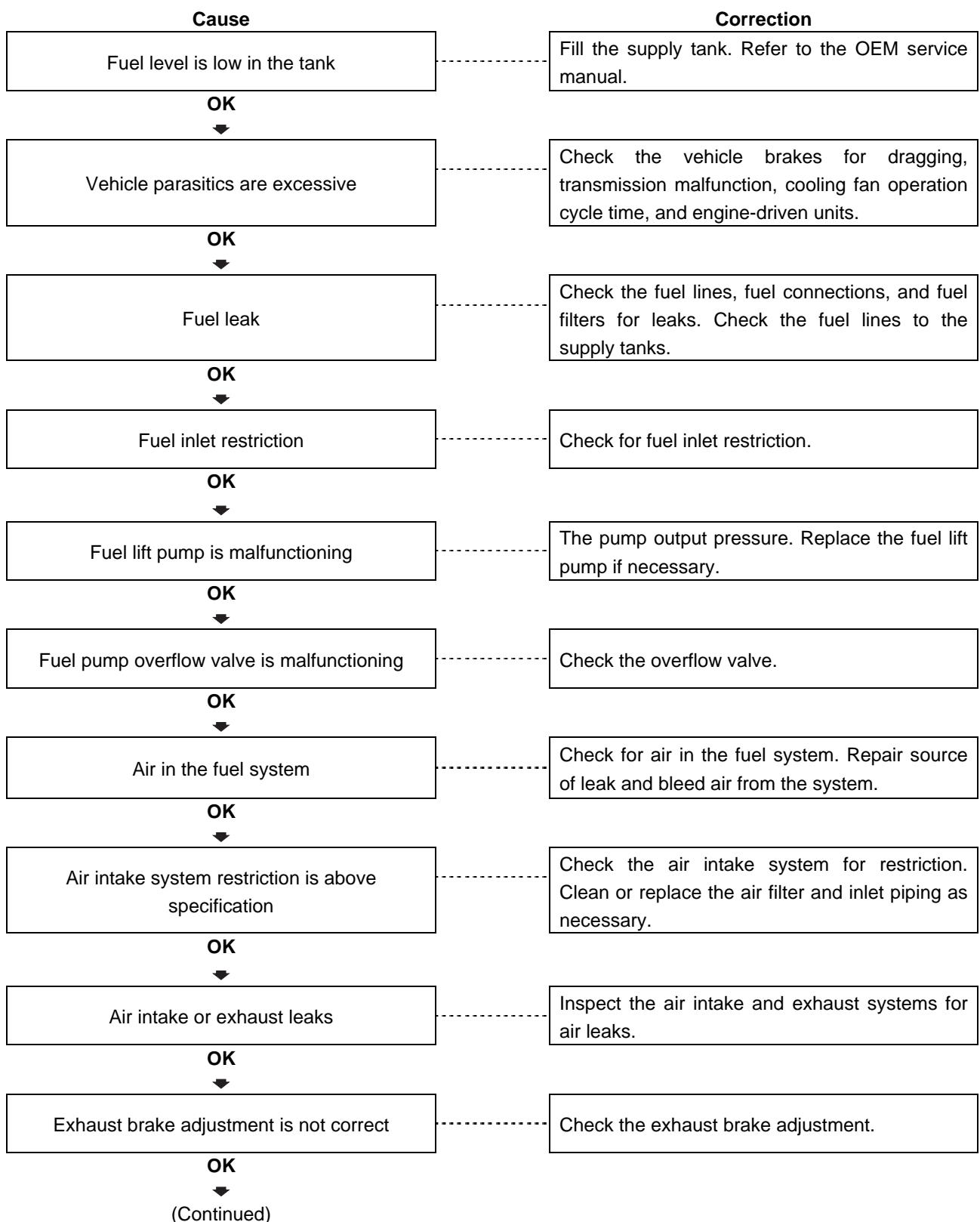
- Get all the facts concerning the complaint
- Analyze the problem thoroughly
- Relate the symptoms to the basic engine systems and components
- Consider any recent maintenance or repair action that can relate to the complaint
- Double-check before beginning any disassembly
- Solve the problem by using the symptom charts and doing the easiest things first
- Determine the cause of the problem and make a thorough repair
- After repairs have been made, operate the engine to make sure the cause of the complaint has been corrected

Troubleshooting Symptoms Charts

Use the charts on the following pages of this section to aid in diagnosing specific engine symptoms. Read each row of blocks from top to bottom. Follow through the chart to identify the corrective action.

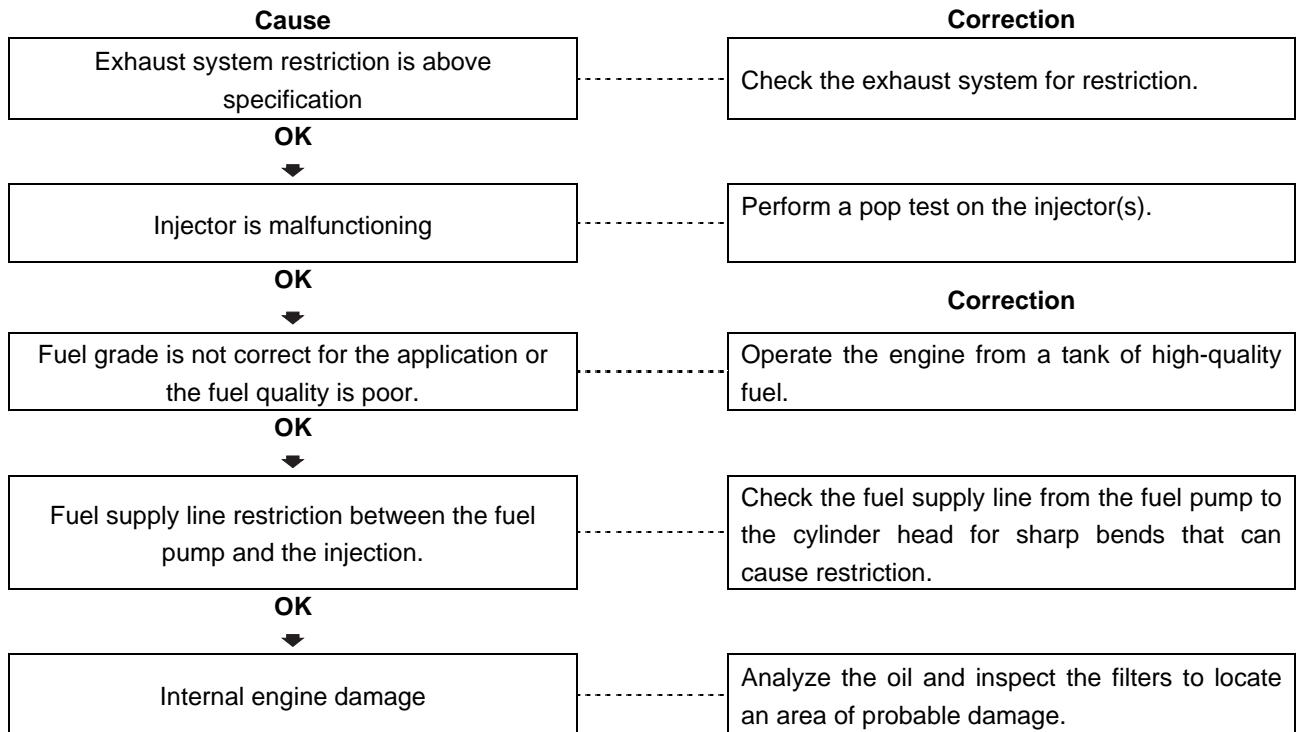
Engine Acceleration or Response Poor

This is symptom tree T-033



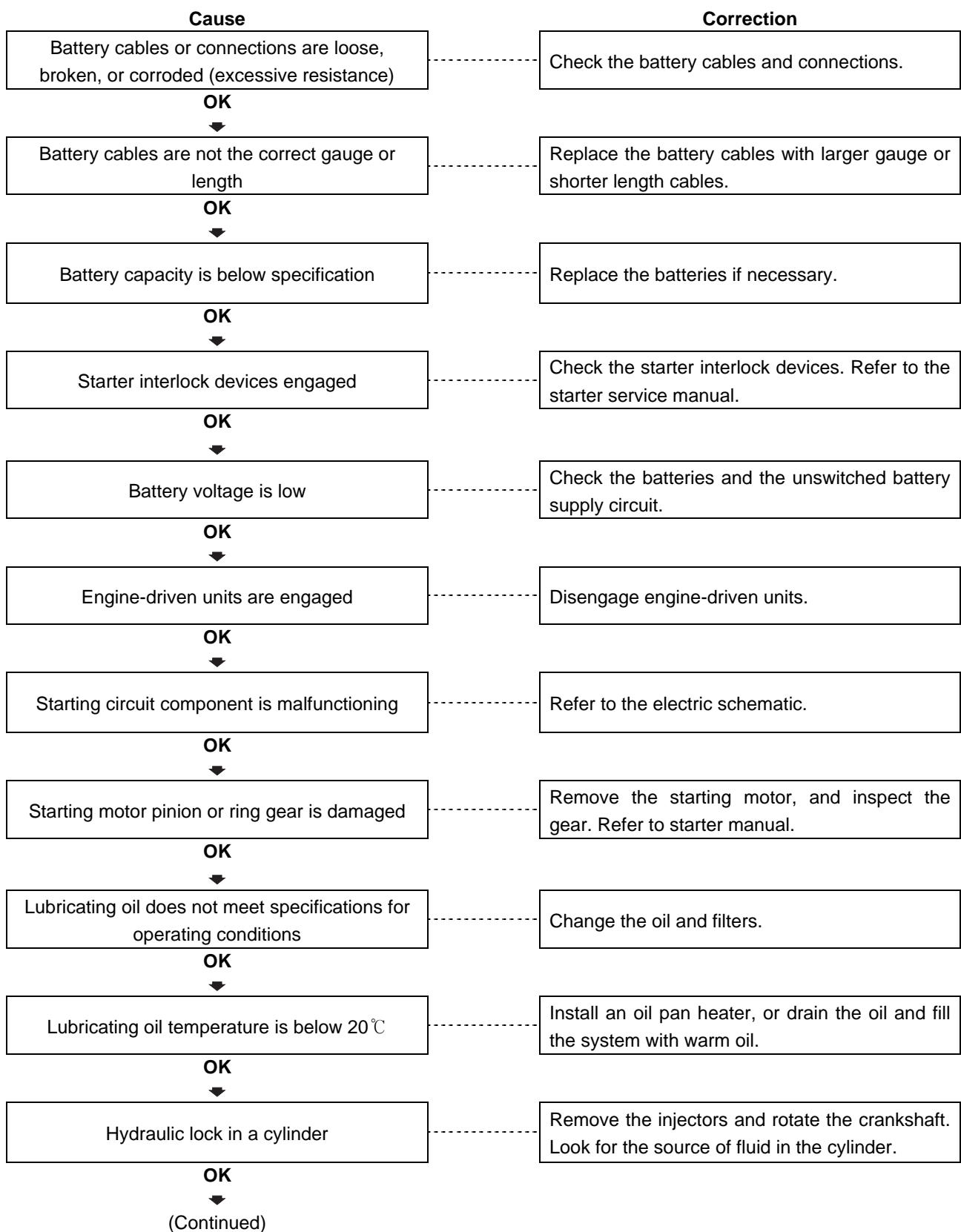
(Continued)

Engine Acceleration or Response Poor (Continued)

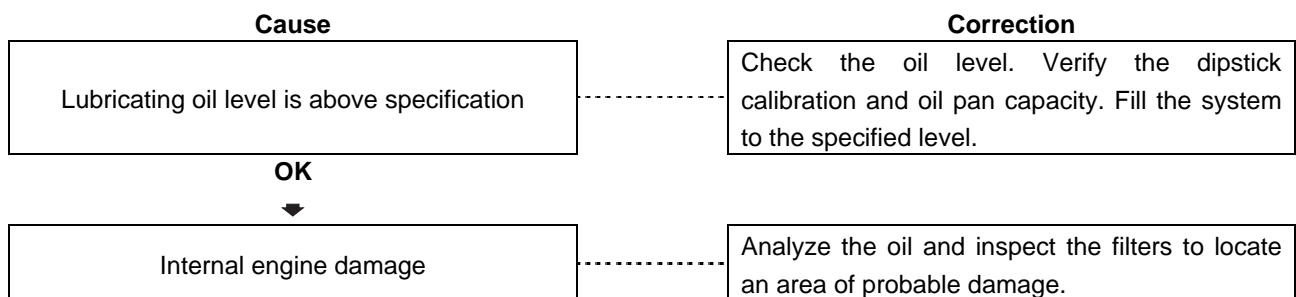


Engine Will Not Crank or Cranks Slowly

This is symptom tree T-078.

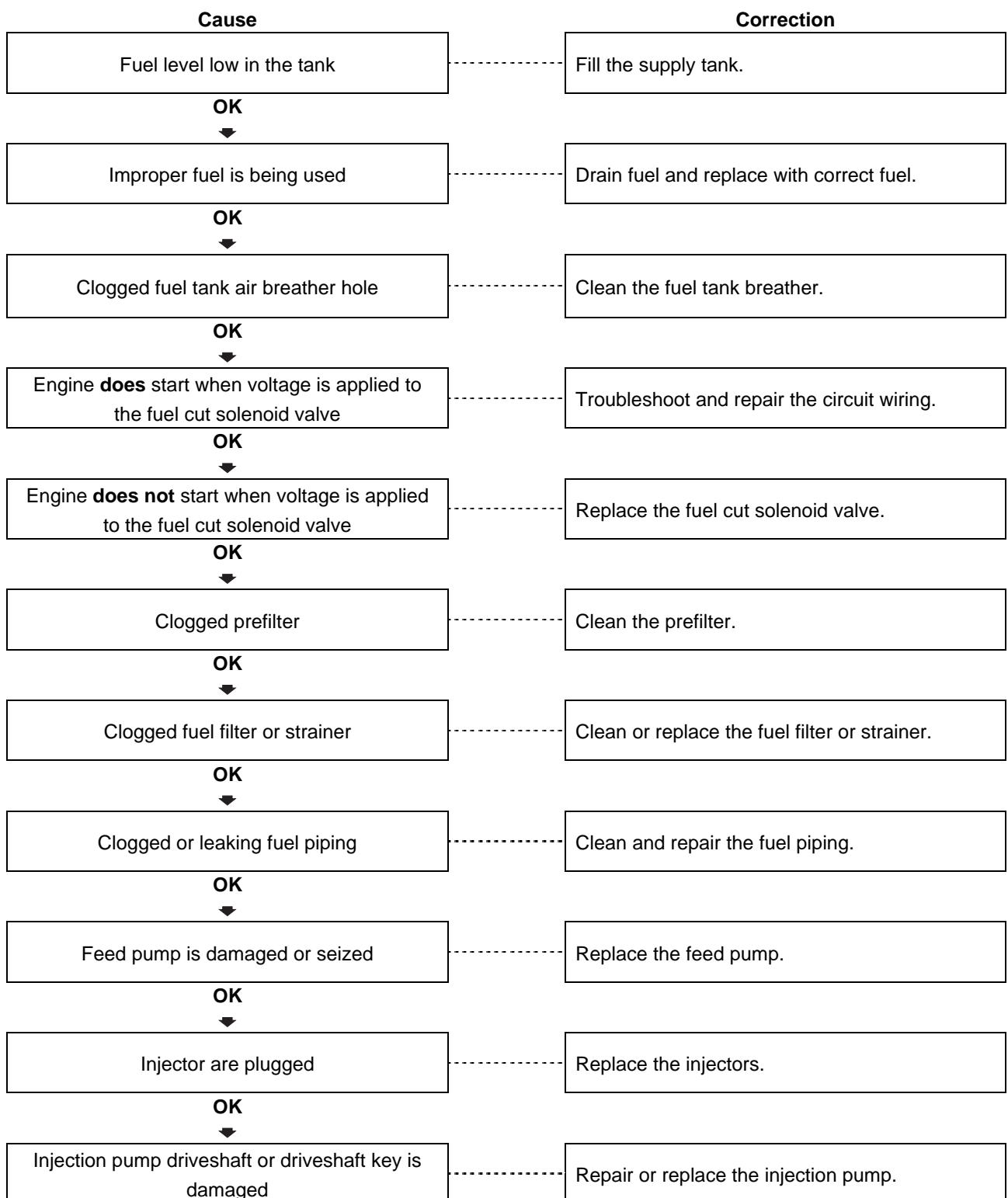


Engine Will Not Crank or Cranks Slowly (Continued)



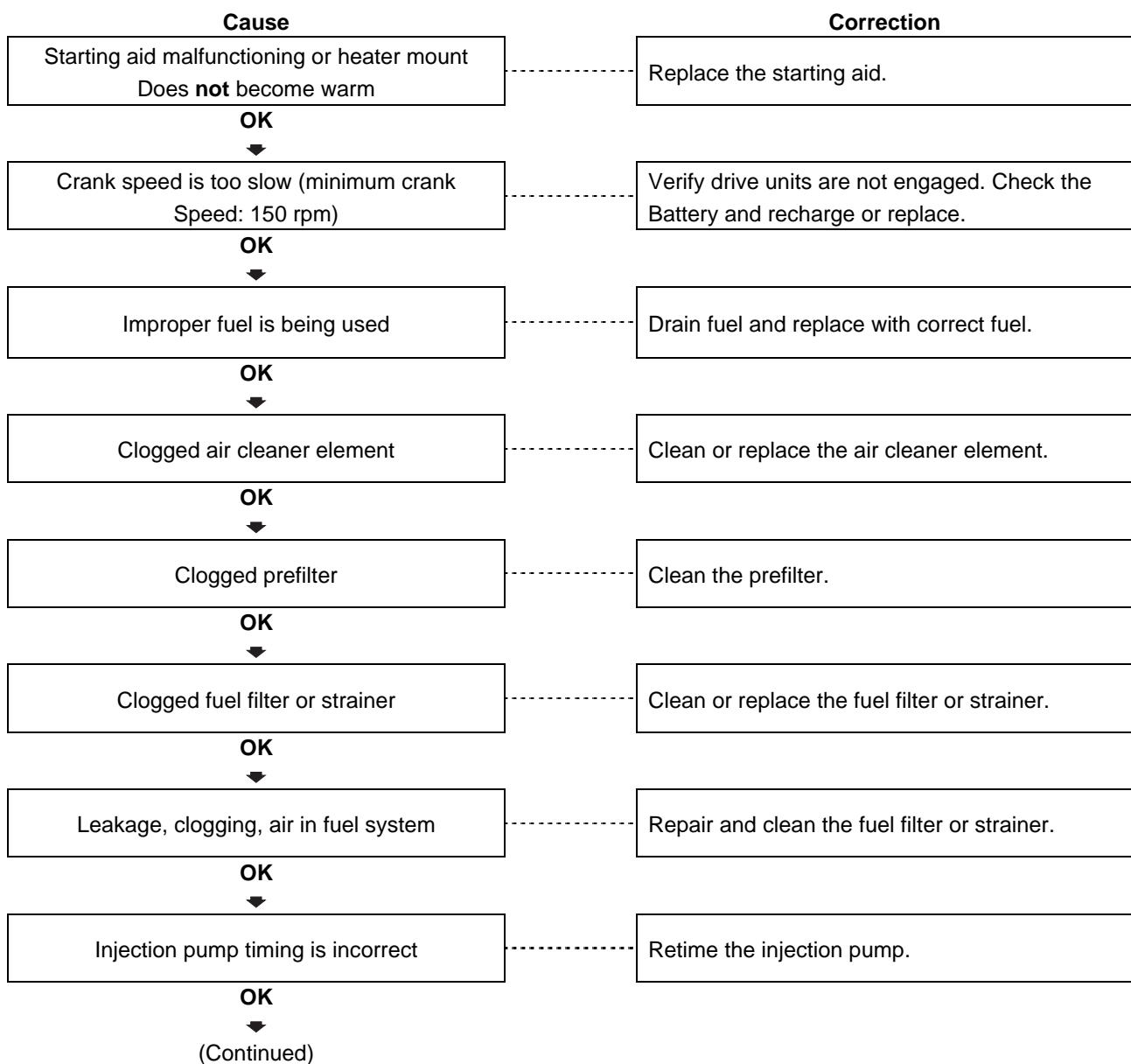
Engine Cranks But Will Not Start (No Exhaust Smoke)

This is symptom tree T-003.

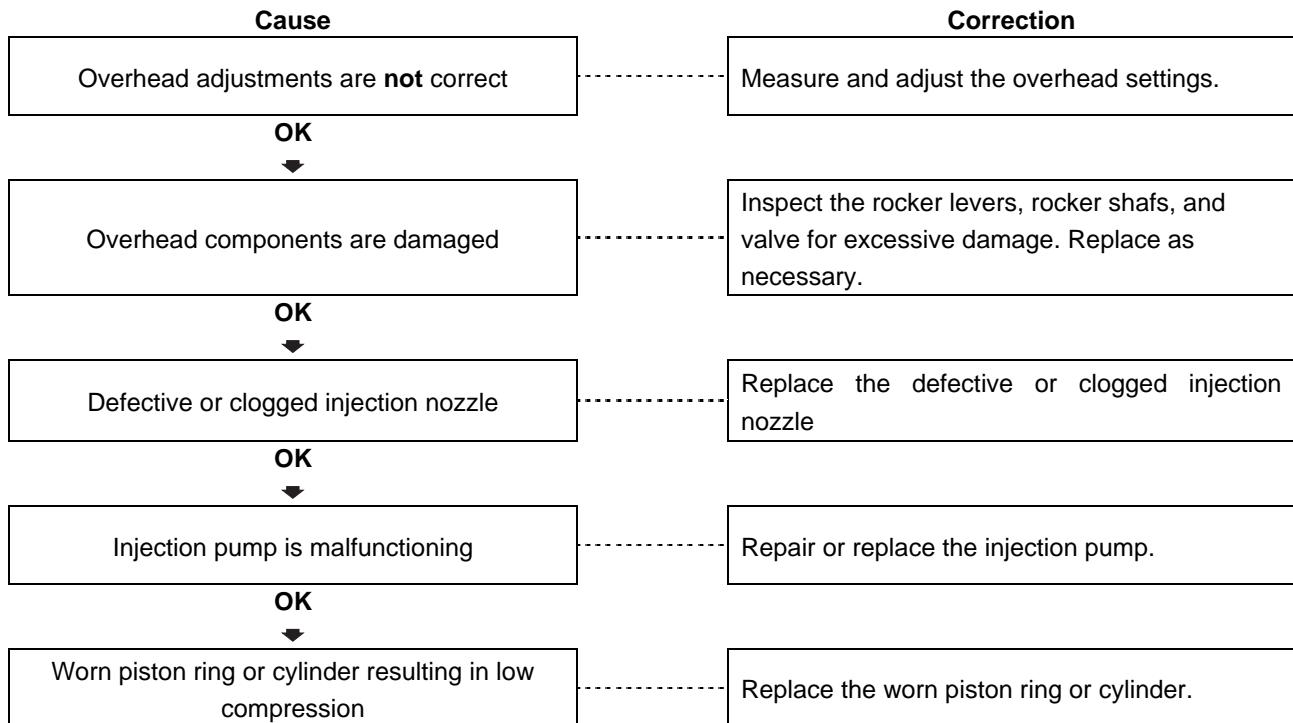


Engine Difficult to Start or Will Not Start (Exhaust Smoke)

This is symptom tree T-004.

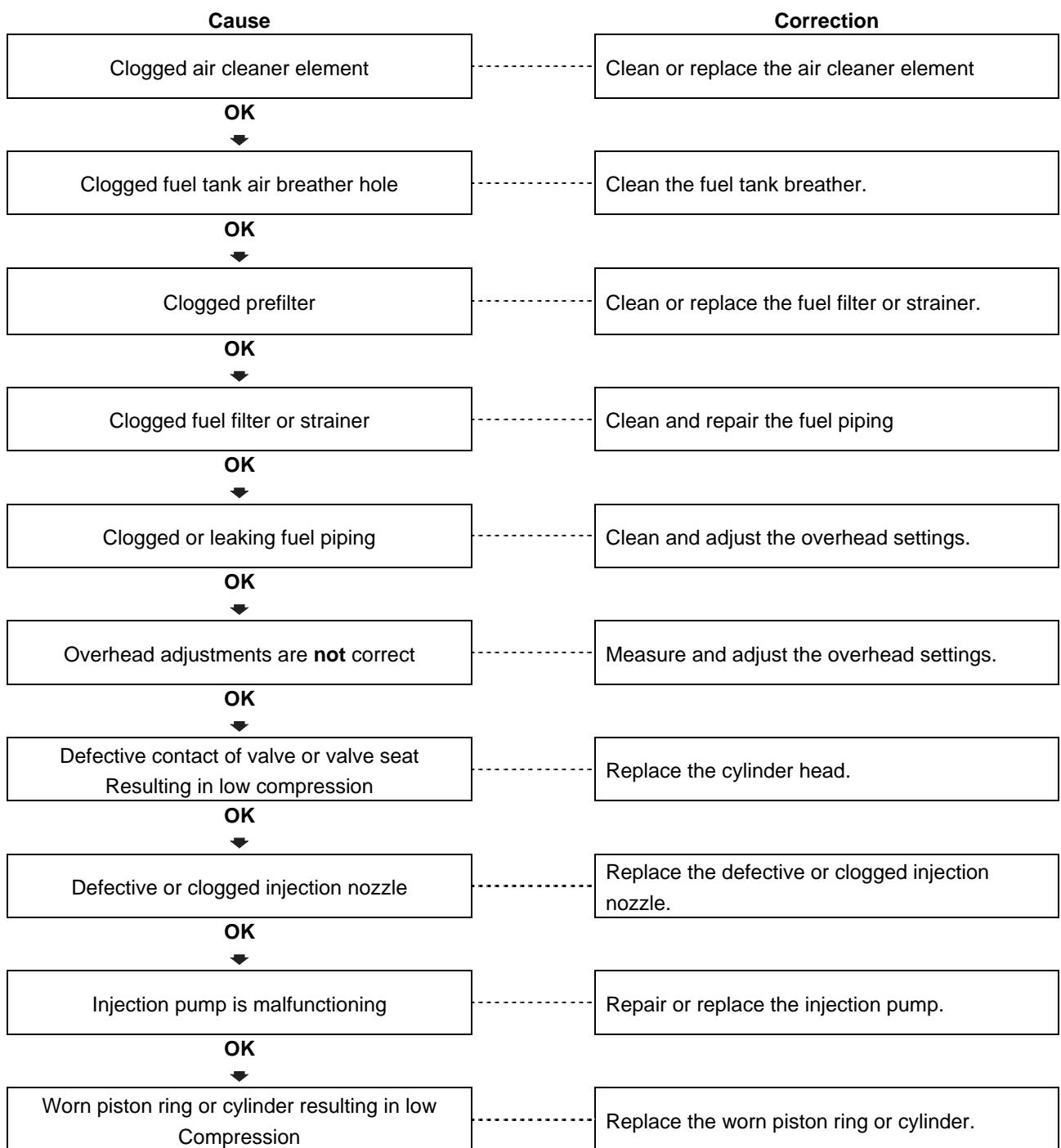


Engine Difficult to Start or Will Not Start (Exhaust Smoke) (Continued)



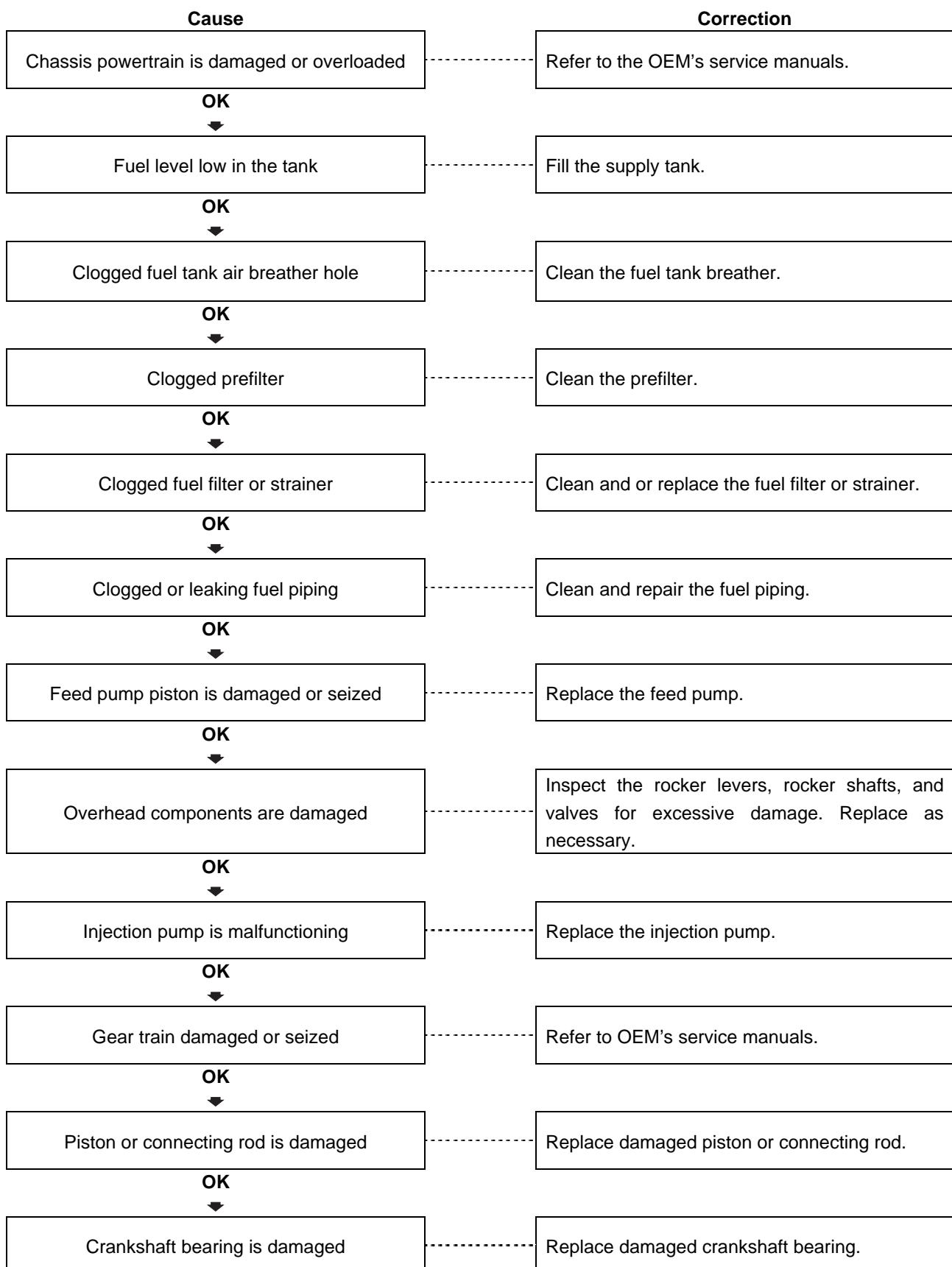
Engine Has Poor Responses

This is symptom tree T-005.



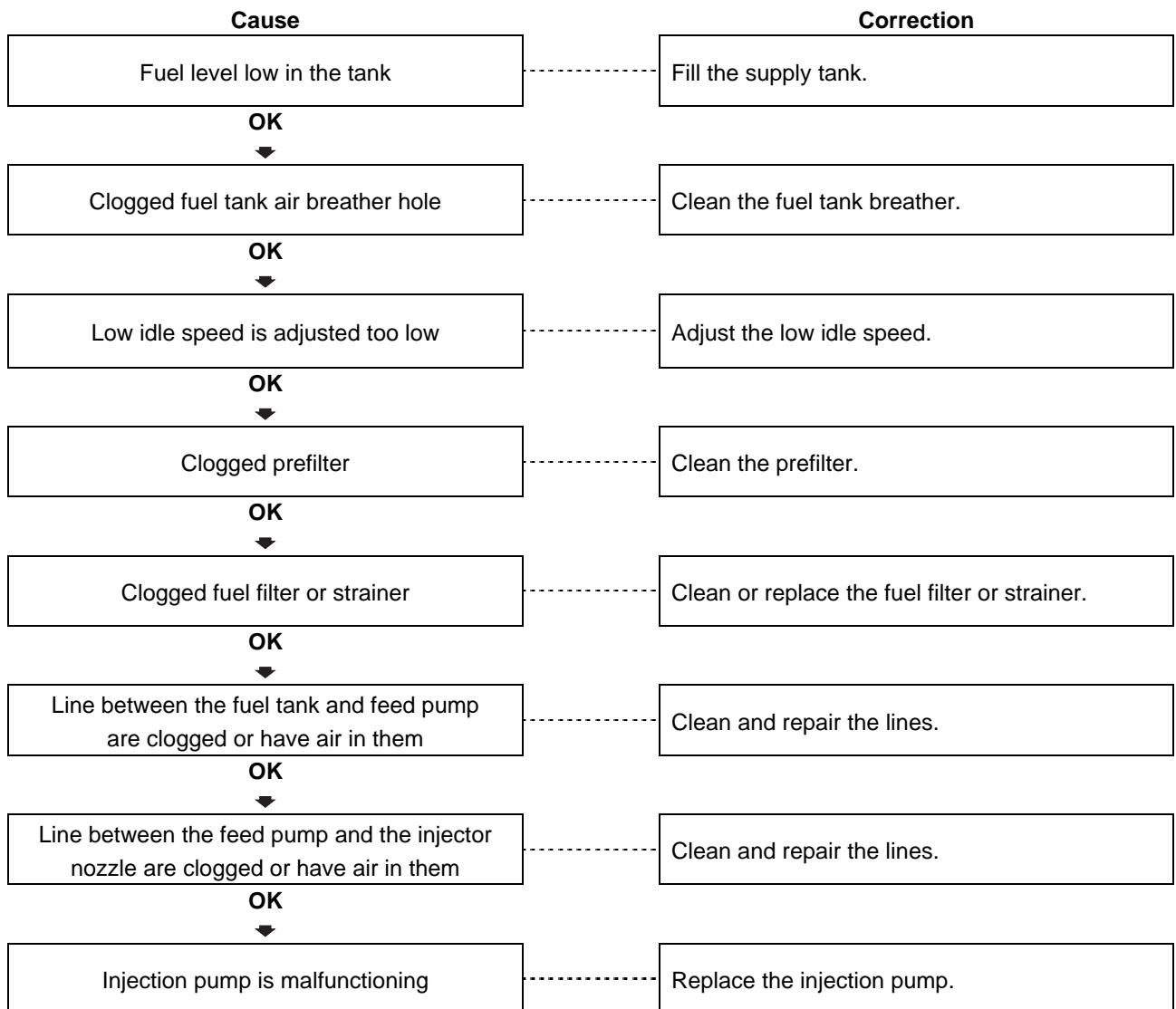
Engine Stops During Operation

This is symptom tree T-006.



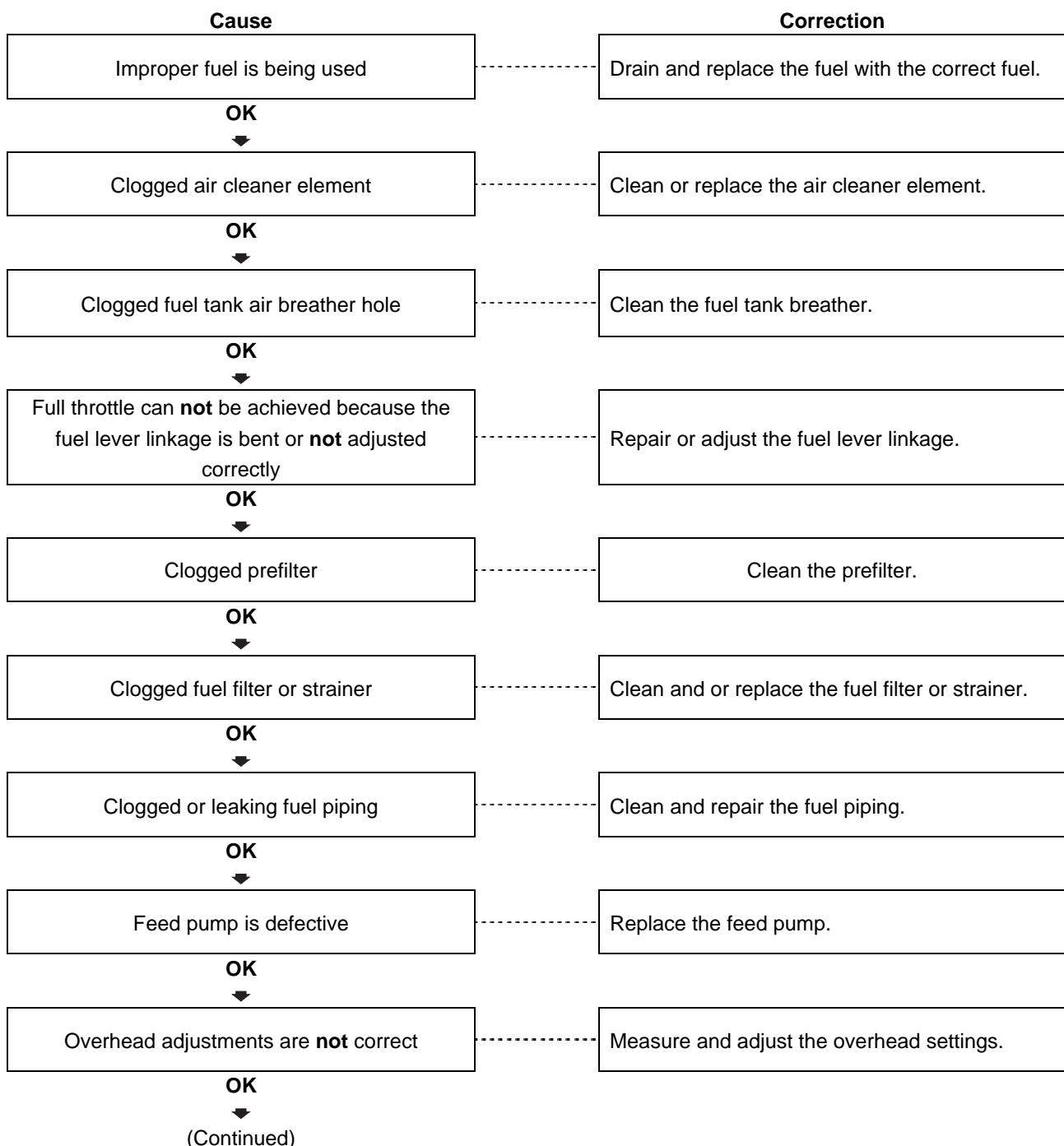
Engine Runs Rough or Misfires

This is symptom tree T-007.

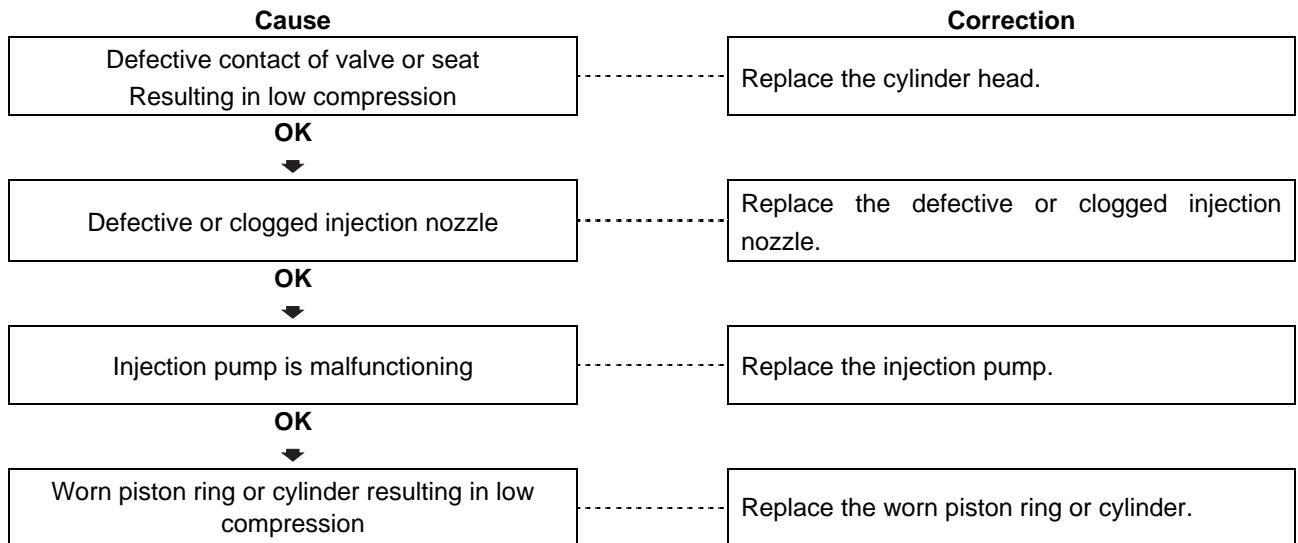


Engine Power Output Low

This is symptom tree T-008.

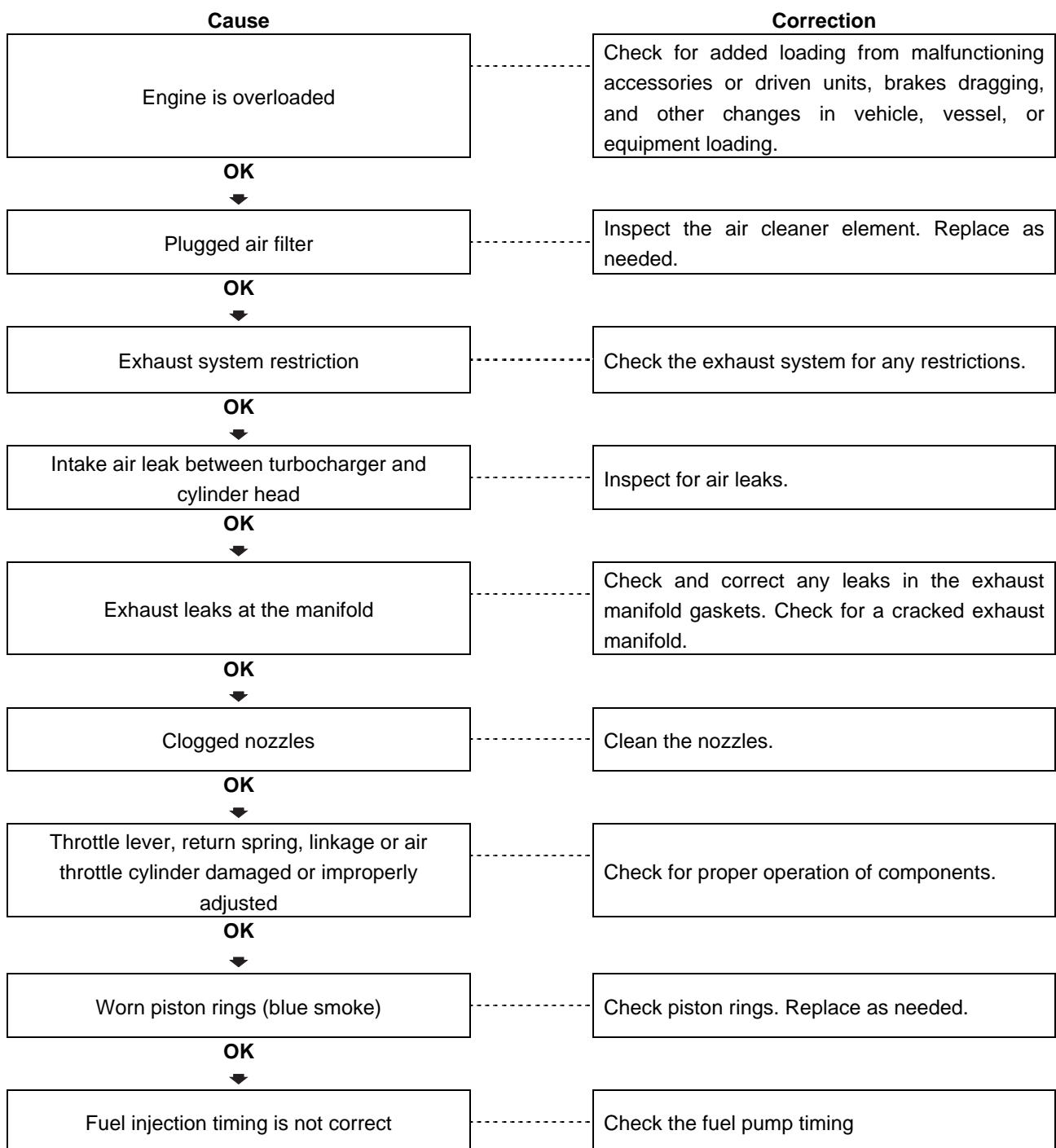


Engine Power Output Low (Continued)



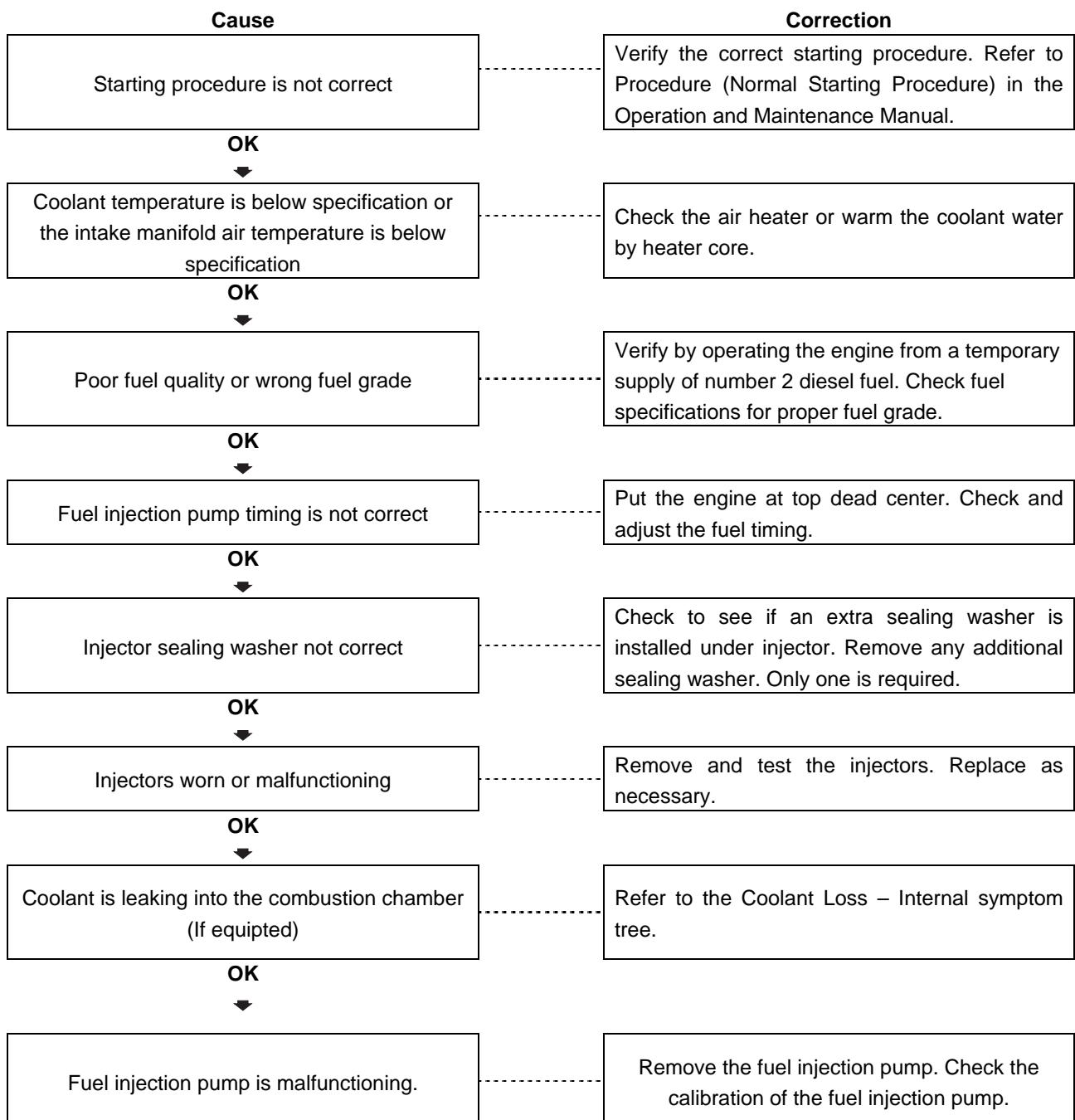
Excessive Exhaust (Black Smoke)

This is symptom tree T-009.



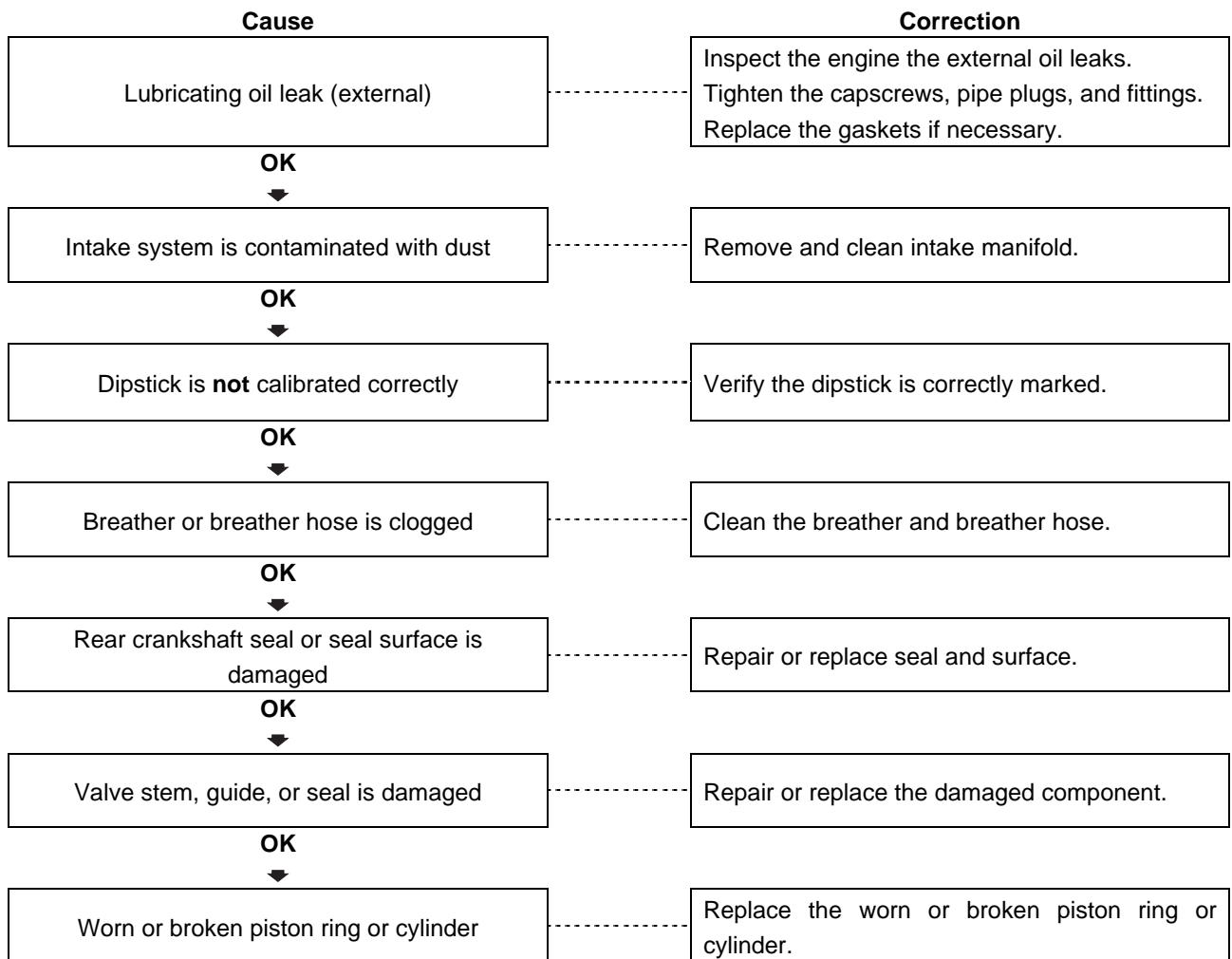
Excessive Exhaust (White Smoke)

This is symptom tree T-009.



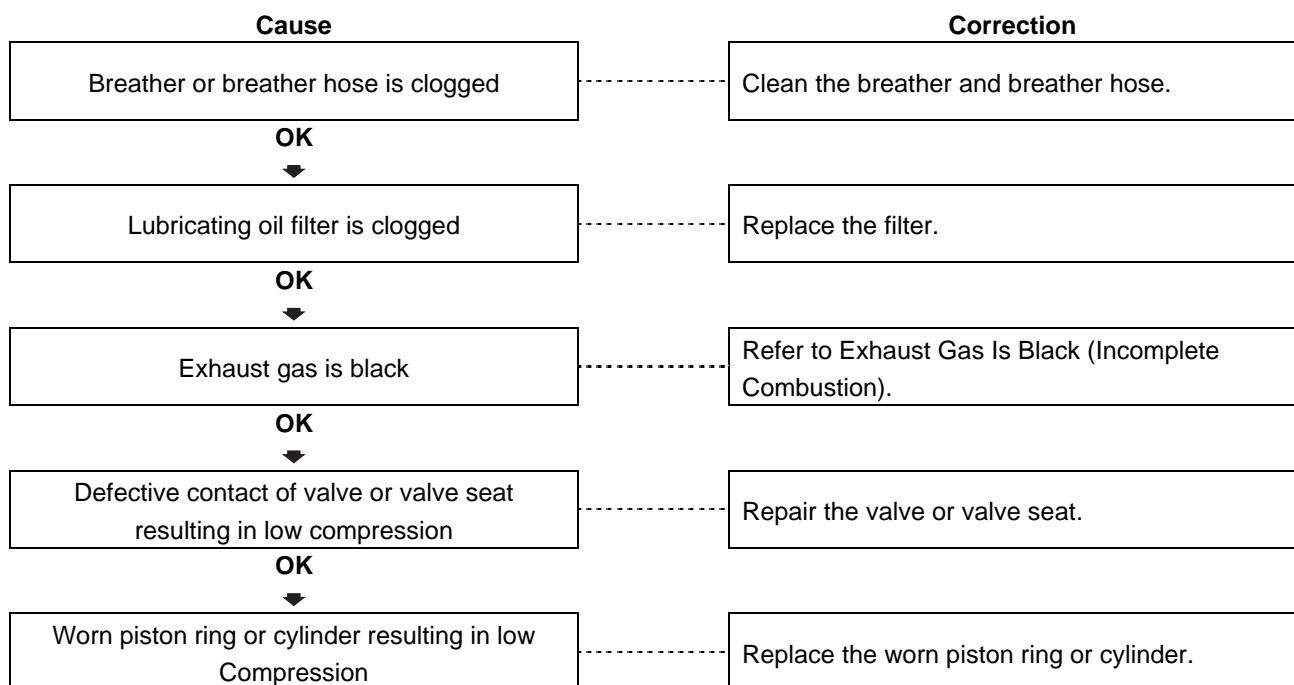
Lubricating Oil Consumption Excessive

This is symptom tree T-010.



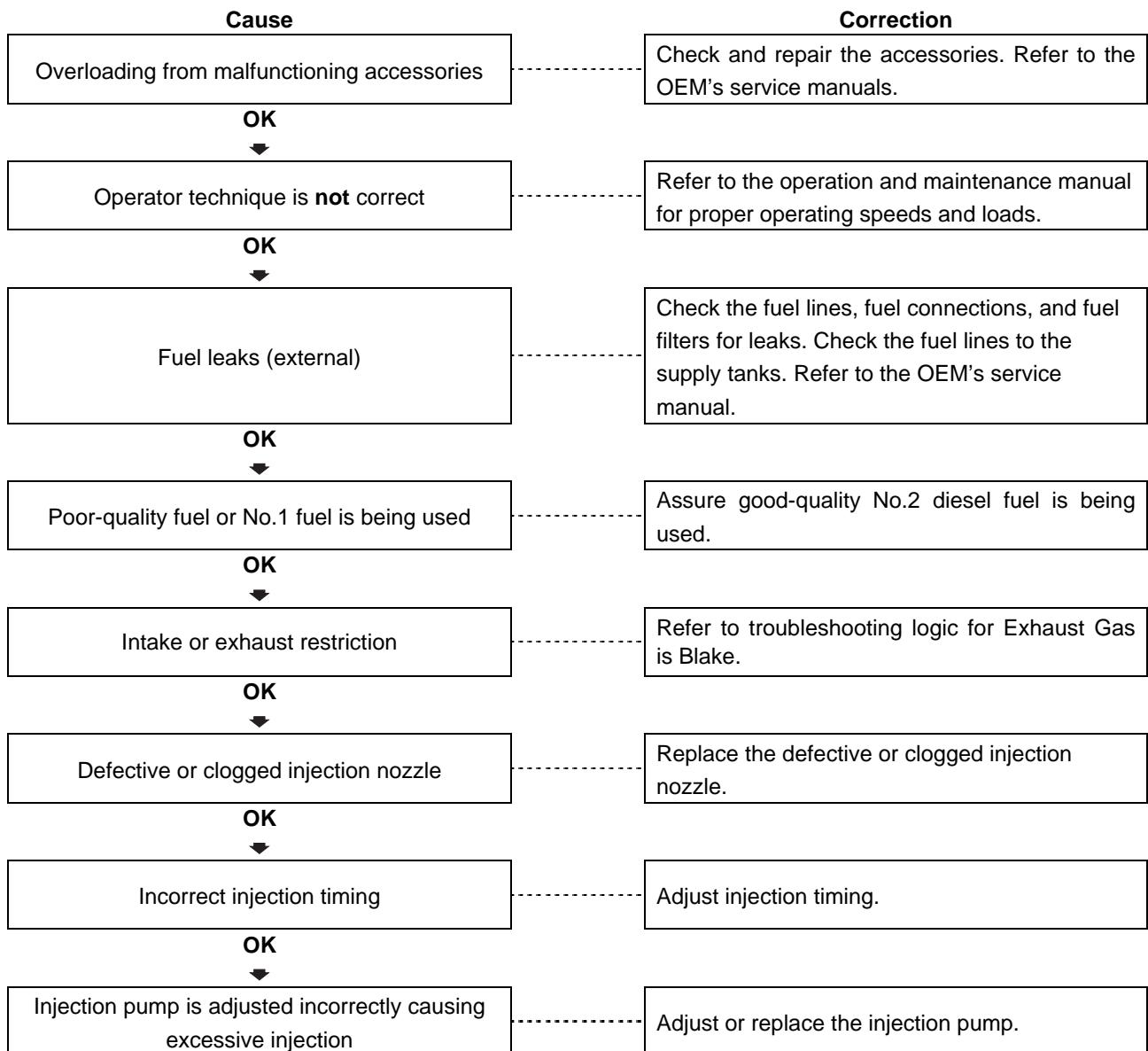
Lubricating Oil Contaminated

This is symptom tree T-011.



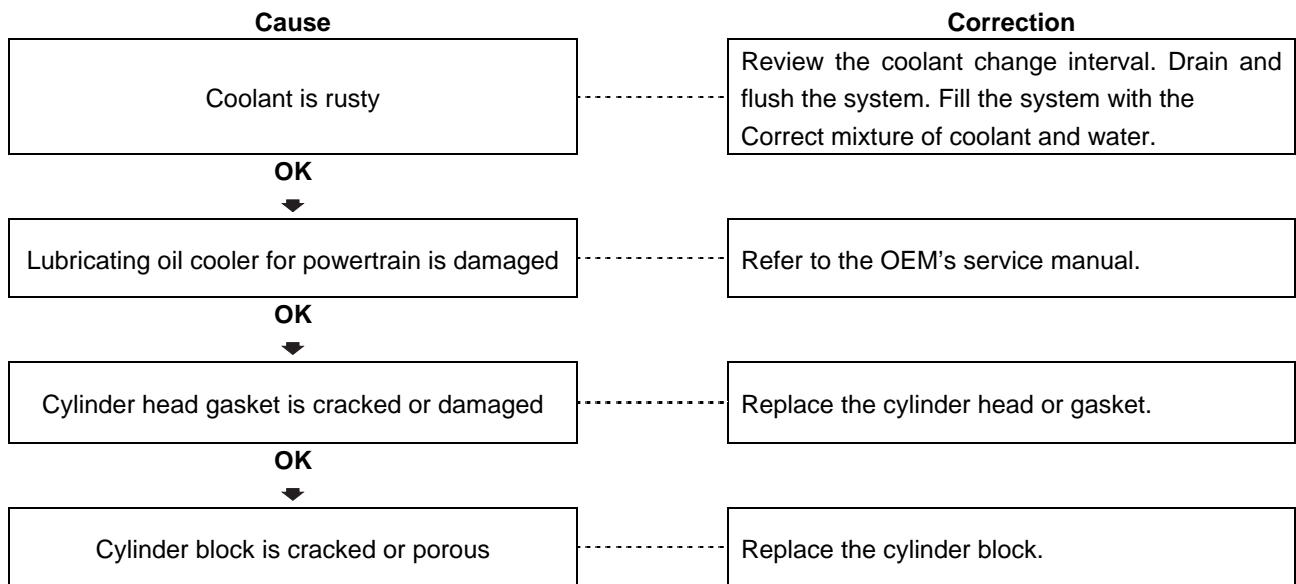
Fuel consumption Is Excessive

This is symptom tree T-012.



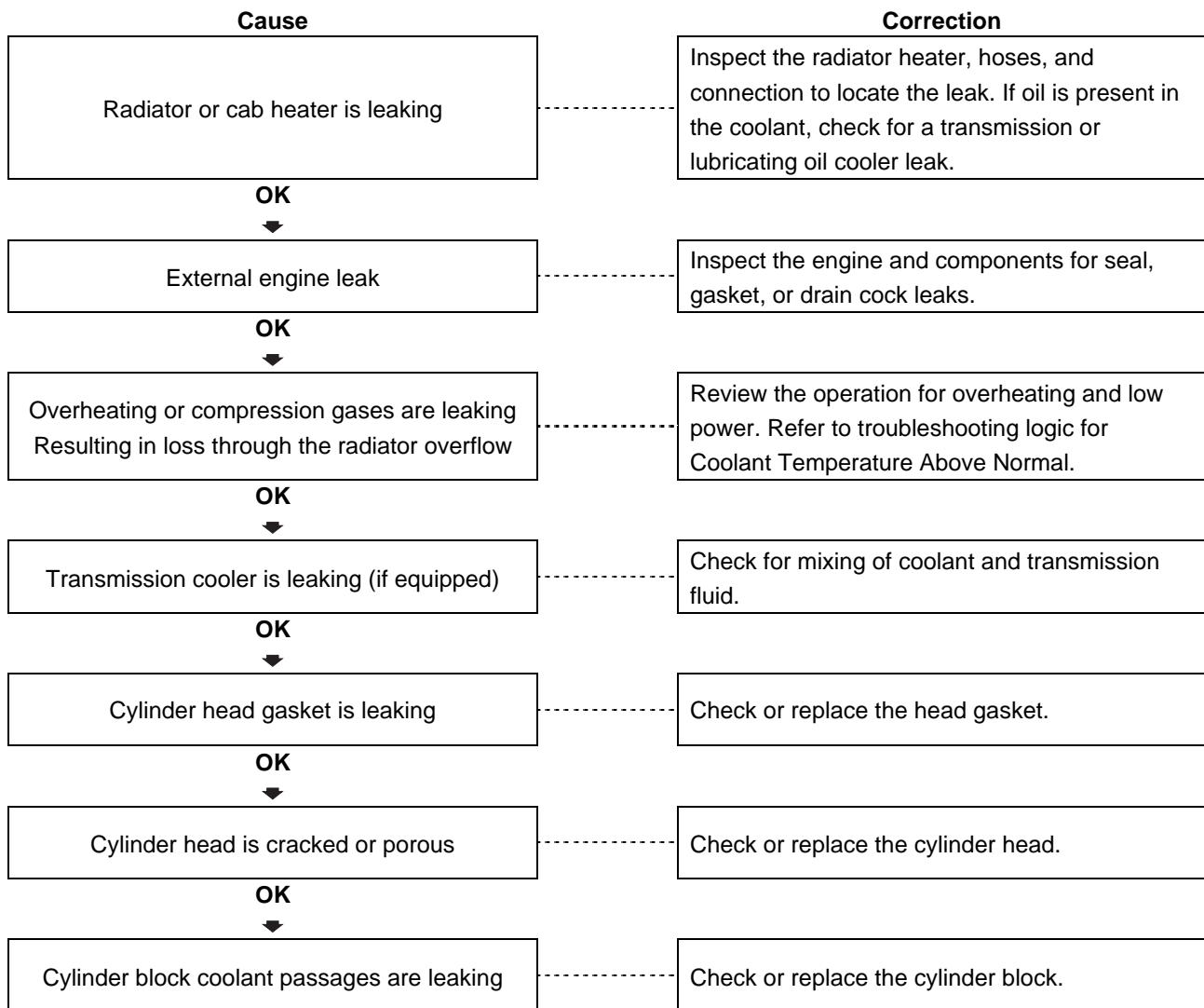
Coolant Contamination

This is symptom tree T-013.



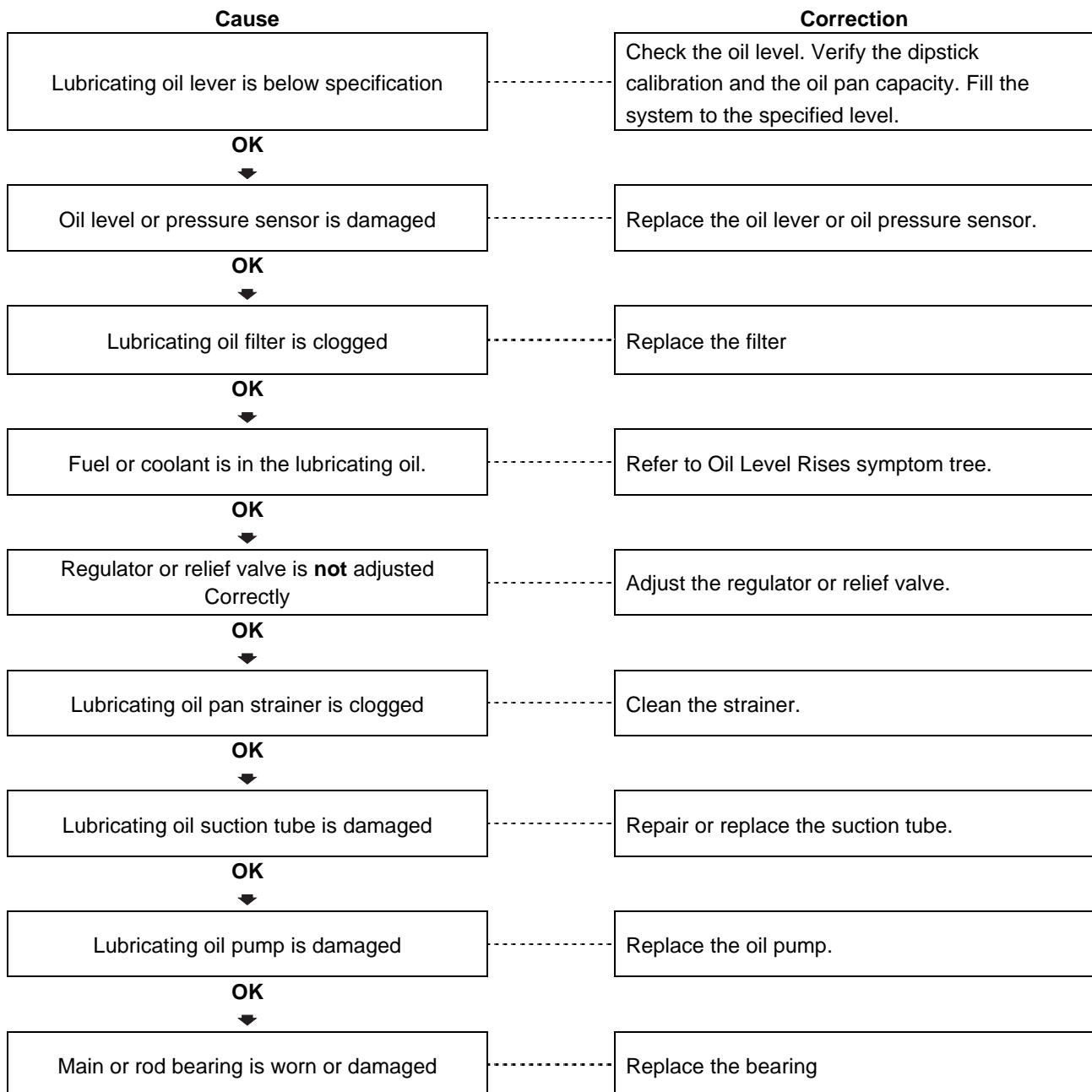
Coolant Loss

This is symptom tree T-013.1



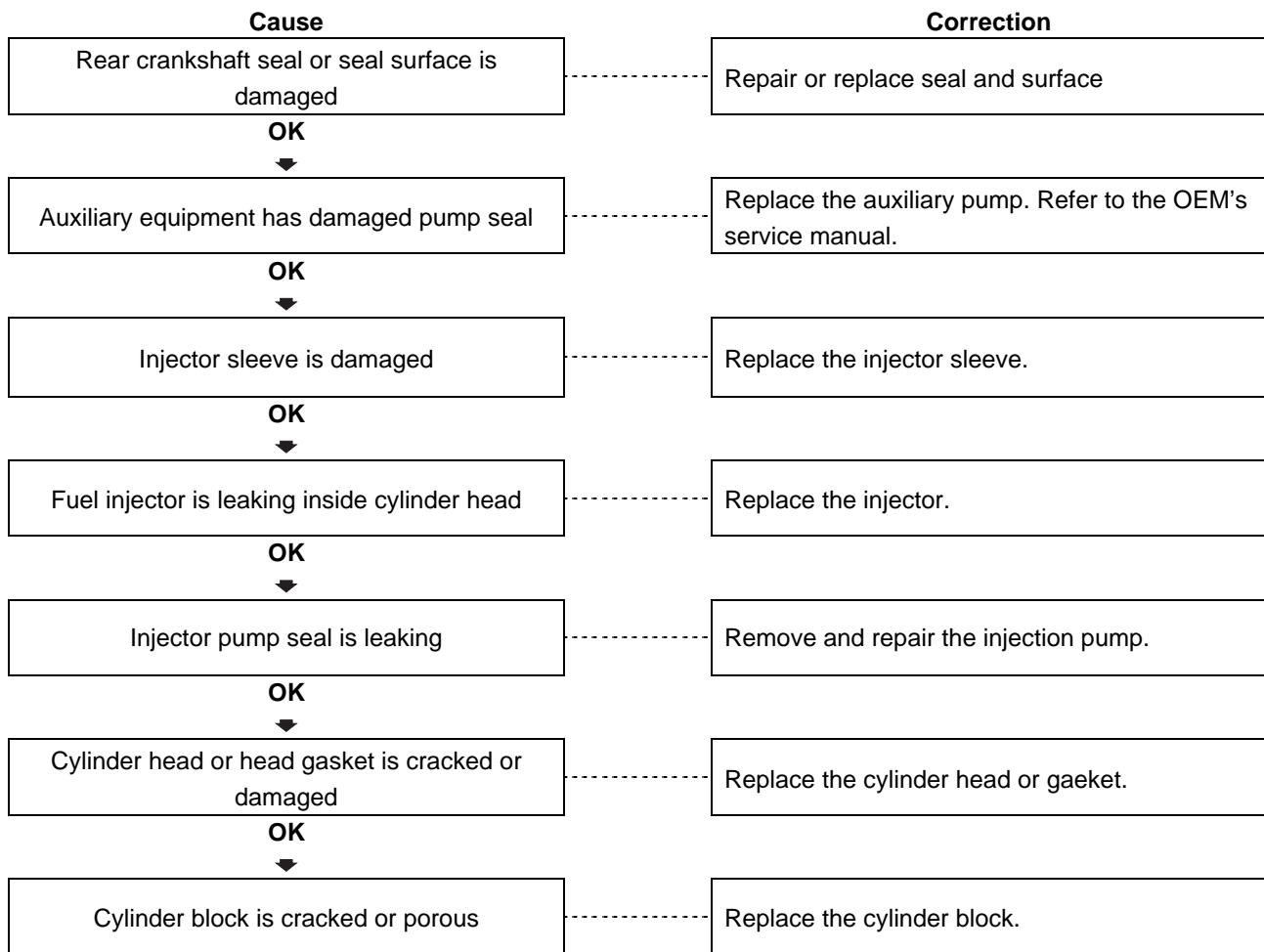
Lubricating Oil Pressure Is Low

This is symptom tree T-014.



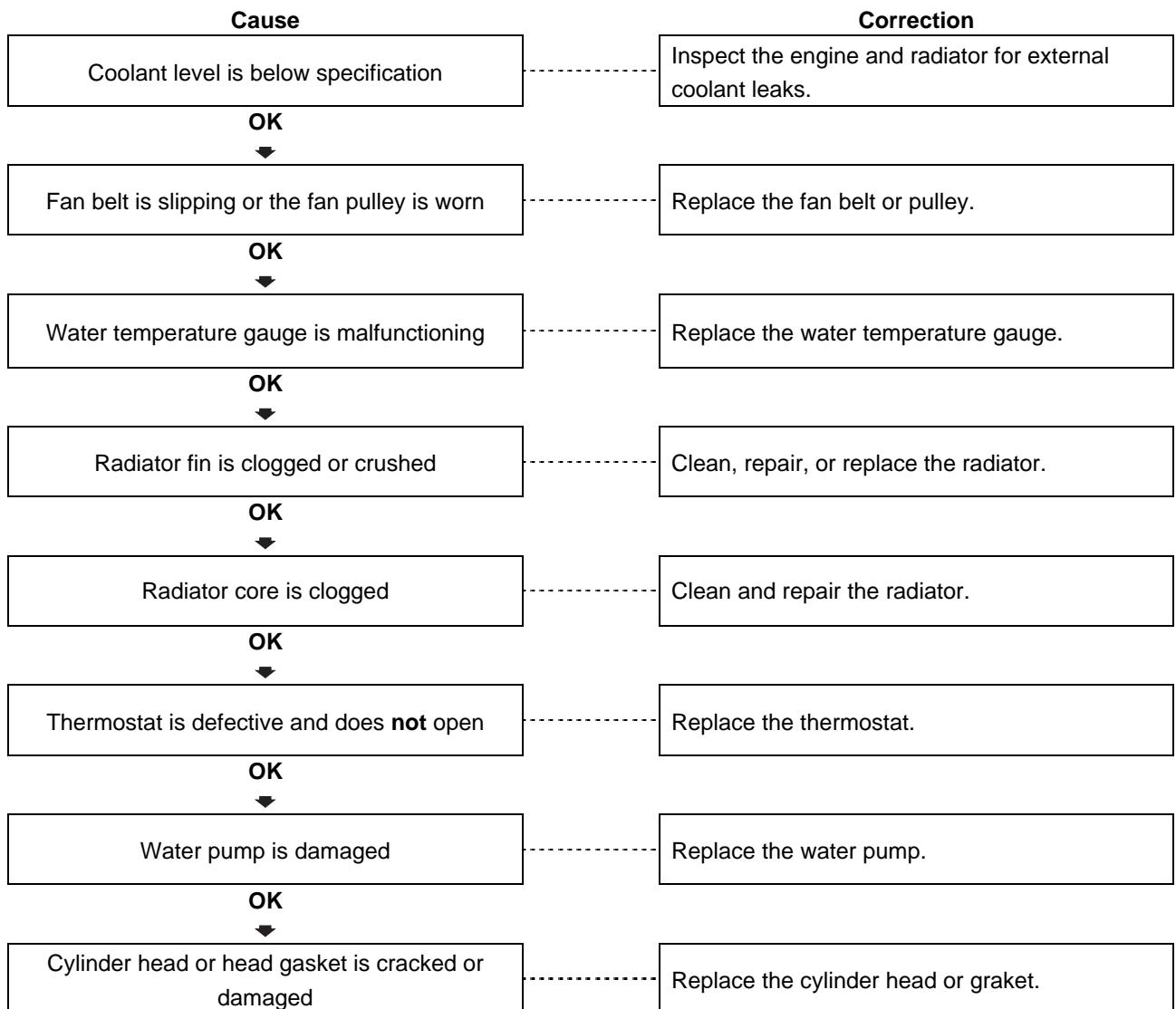
Oil Level Rises

This is symptom tree T-015.



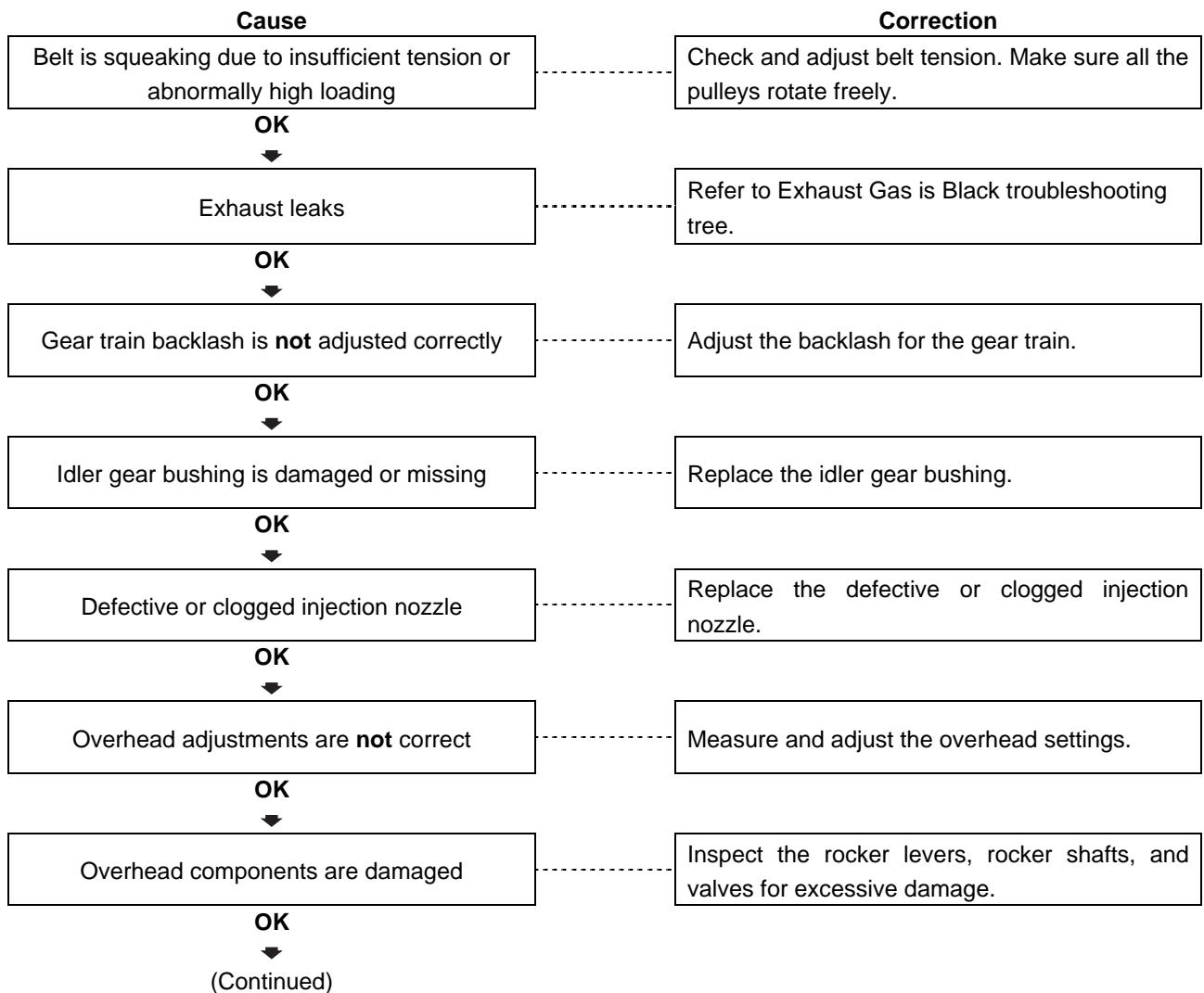
Coolant Temperature above Normal

This is symptom tree T-016.

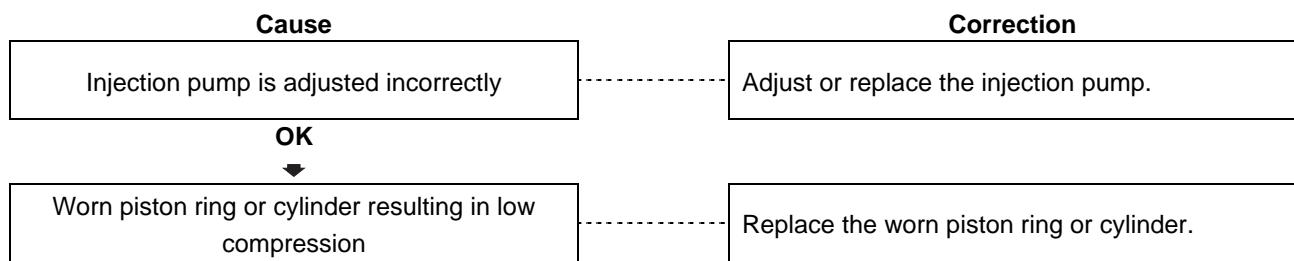


Excessive Noise

This is symptom tree T-017.

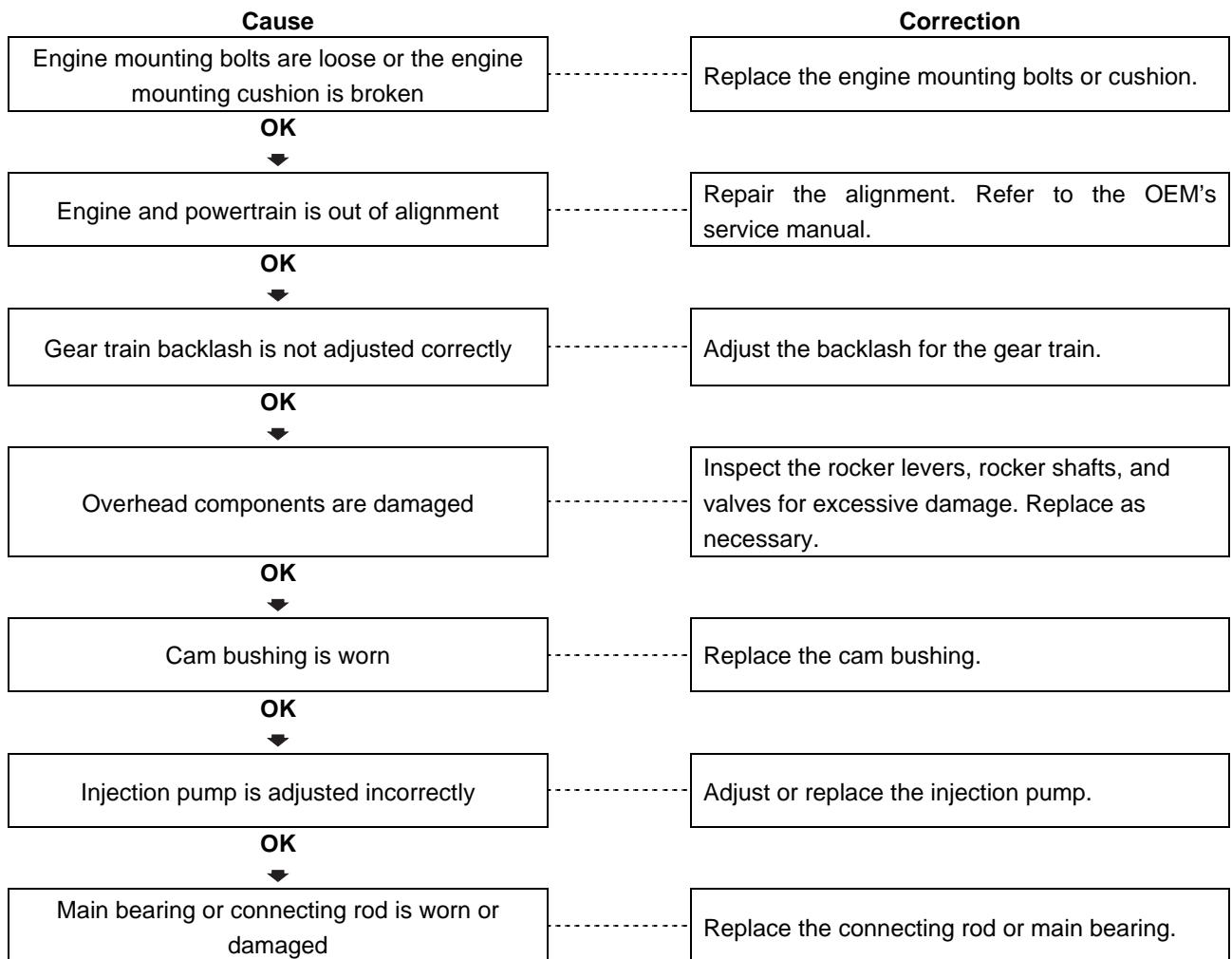


Excessive Noise (Continued)



Engine Vibration Excessive

This is symptom tree T-018.

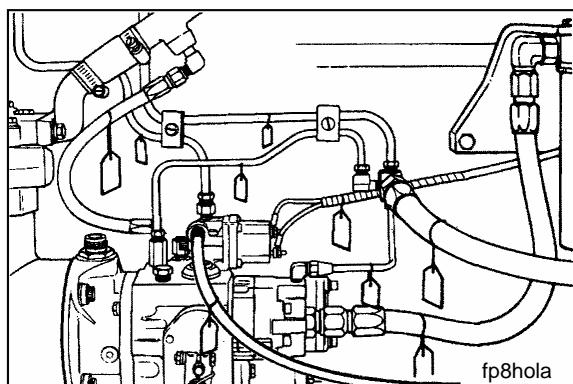


Complete Engine

Engine Disassembly

Service Tool

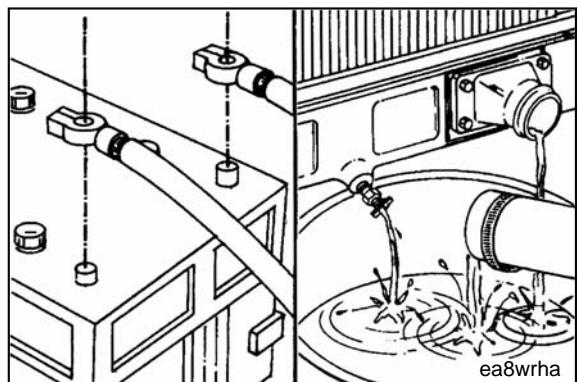
Part No.	Part Name	Quantity
3375193 or 3375194	Unit Repair Stand or Engine Overhaul Stand	1
3163625	Bracket	1
3163292	Valve Spring Compressor	1
3397890	Flange Puller	1
3823137	Piston Ring Expansion Tool	1



Engine Removal



NOTE: Put tag on all hoses, lines, linkage, and electrical connections as they are removed to identify location and aid the installation process.



WARNING

Always disconnect the negative (-) cable first.



Disconnect the battery cables.

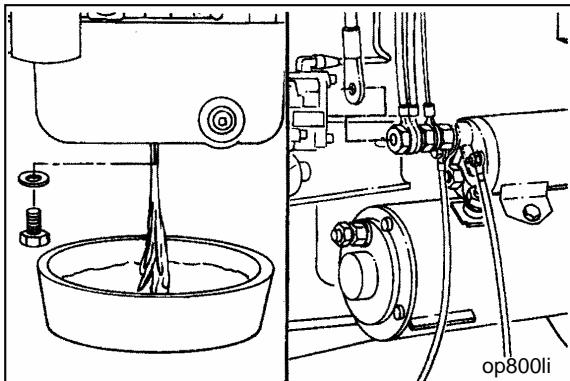
WARNING

Allow the engine to cool before draining to avoid burns from hot liquid.

WARNING

Coolant is toxic. Keep away from children and animals. Save for reuse or dispose of in accordance with local regulations.

Drain the engine coolant.



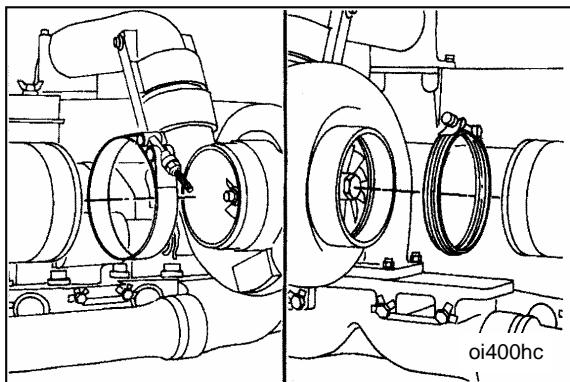
⚠️ WARNING

Some state and federal agencies in the United States of America have determined that used oil is carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. Always use the proper procedures to dispose of the oil.

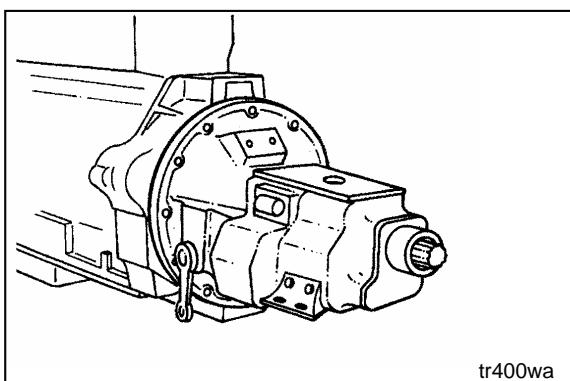
Drain the lubricating oil.

Engine Oil: 7.5 liters [1.98 U.S.gal]

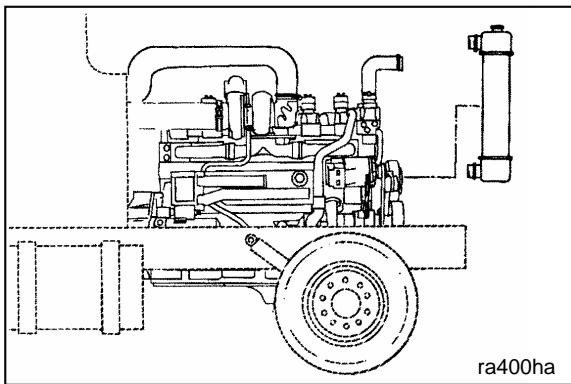
Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires and hydraulic lines.



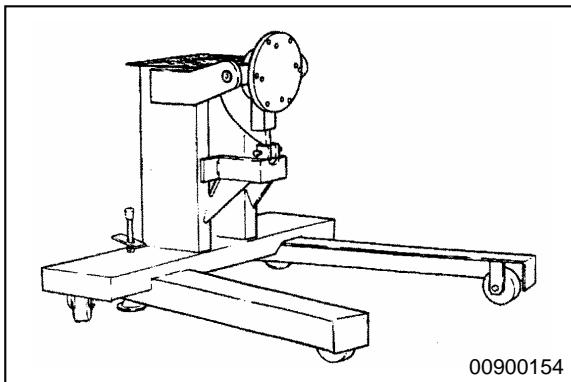
Disconnect the intake and exhaust system pipes.



Disconnect the drive units from the flywheel housing and flywheel.

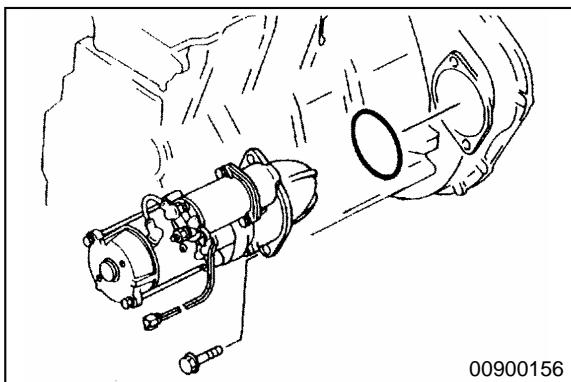


Remove all chassis components necessary to remove the engine from the equipment.

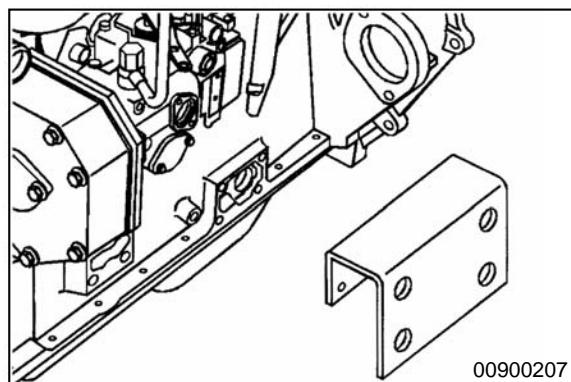


Prepare a stable stand, Part No. 3375193 or 3375194, which will prevent the engine from falling over.

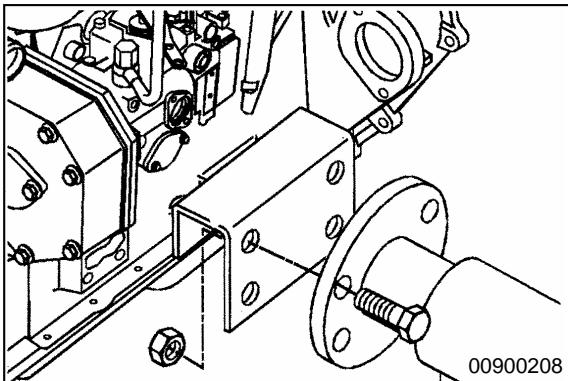
Engine Weight (approx.): 255 kg [562 lb]



Remove the starting motor.



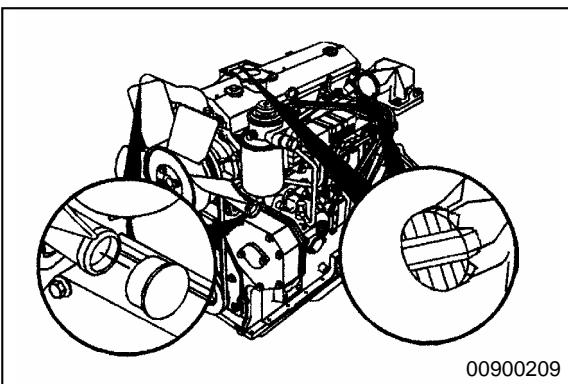
Install the bracket, Part No. 3163625, on the engine.



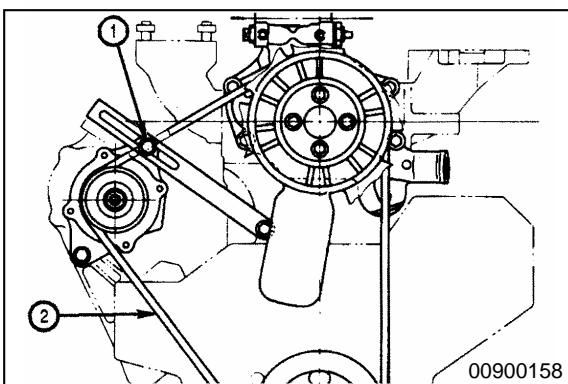
⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Put the engine on the stand.



Cover all the engine openings to prevent dirt and debris from entering the engine.



Fan Pulley

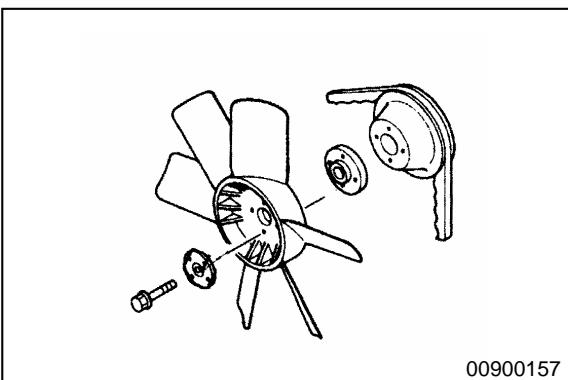
⚠ WARNING

Be careful not to injure your fingers or damage the alternator when moving the alternator toward the cylinder block.

Loosen the mounting capscrew of the adjustment plate (1). Loosen the alternator mounting capscrew and nut.

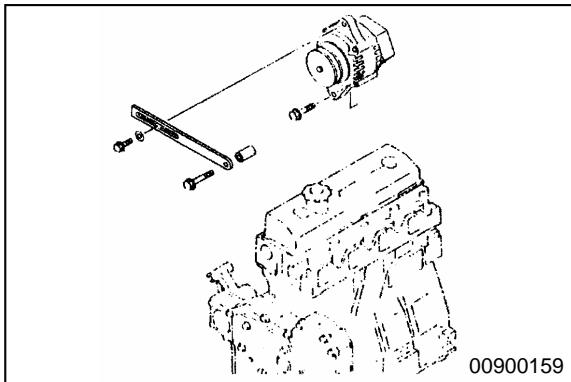
Move the alternator toward the cylinder block, and remove the belt (2).

Remove the fan pulley.



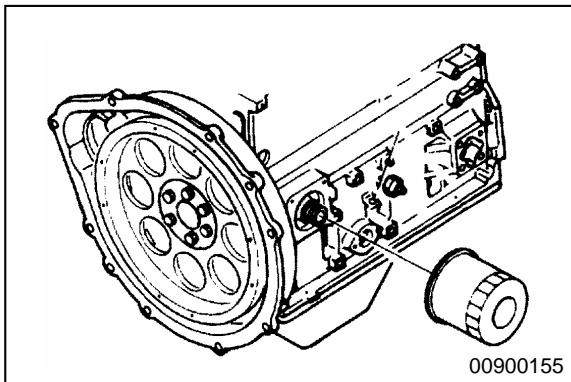
Fan

Remove the four capscrews, retainer plate, fan, and spacer.



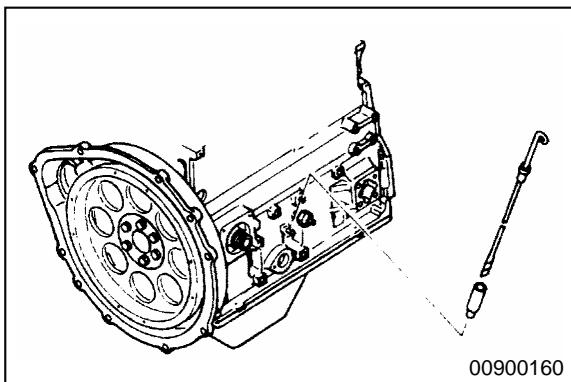
Alternator

Remove the adjusting capscrew and washer.
Remove the capscrew, adjustment plate, and spacer.
Remove the remaining capscrew and alternator.



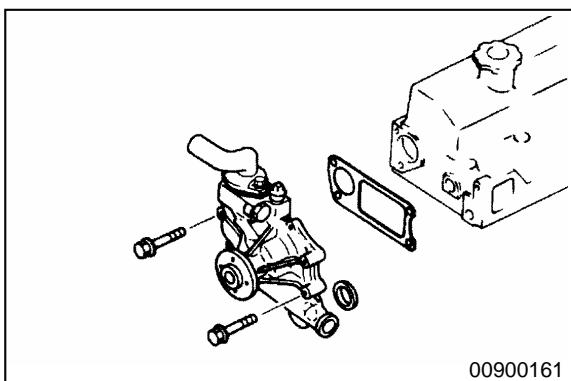
Lubricating Oil Filter

Remove the lubricating oil filter.



Dipstick Guide

Remove the dipstick and dipstick guide.



Water Pump

Remove the mounting capscrews, water pump, gasket, and o-ring.

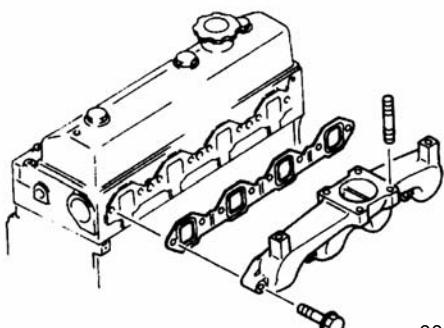
Discard the gasket and o-ring.



18900025

Thermostat

Remove the two mounting capscrews, thermostat housing, thermostat and seal.



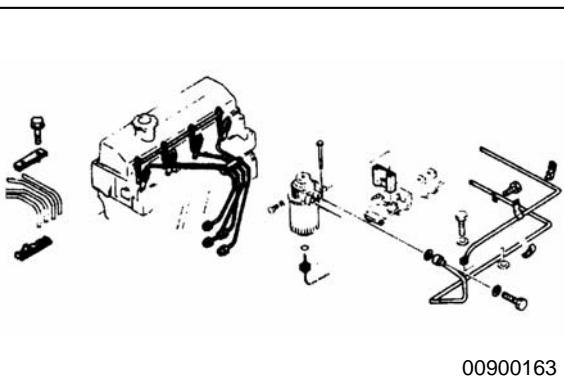
00900162



Exhaust Manifold

Remove the eight capscrews, exhaust manifold, and gasket.

Discard the gasket.



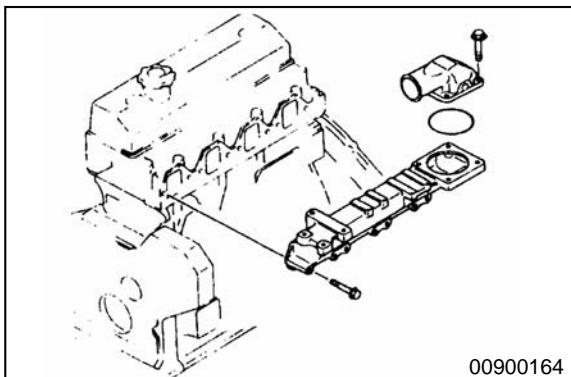
00900163



Fuel Injection Tubing

Remove the clamp.

Remove the sleeve nuts and the fuel injection tubing from the fuel injection pump and the cylinder head.

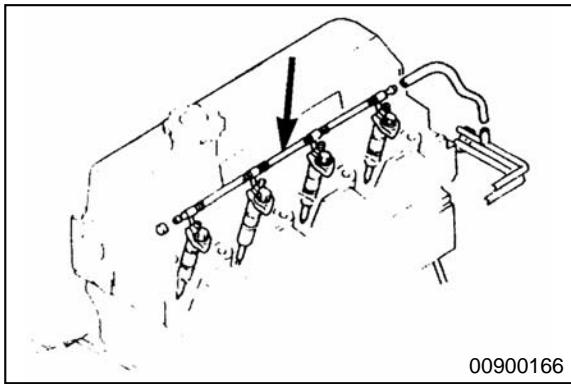


00900164



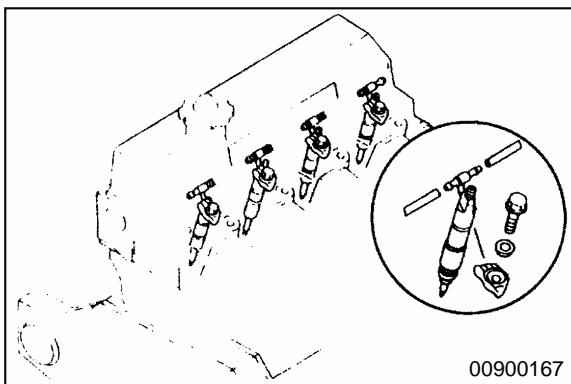
Intake Manifold

Remove the eight capscrews, intake manifold, and air inlet connection. Remove the grid heated, if equipped. Remove the four capscrews, air inlet connection, and o-ring. Discard the o-ring.



Spill Tube

Remove the spring hose clamps and hose. Remove the spill tube.



Injector

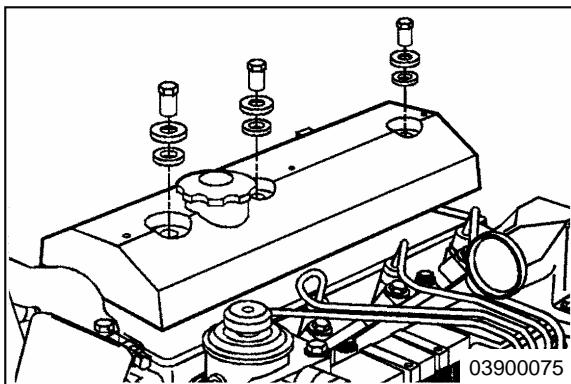
⚠ CAUTION

Be careful not to damage the tip of the injector when removing.

Remove the mounting capscrew, washer, and injector.

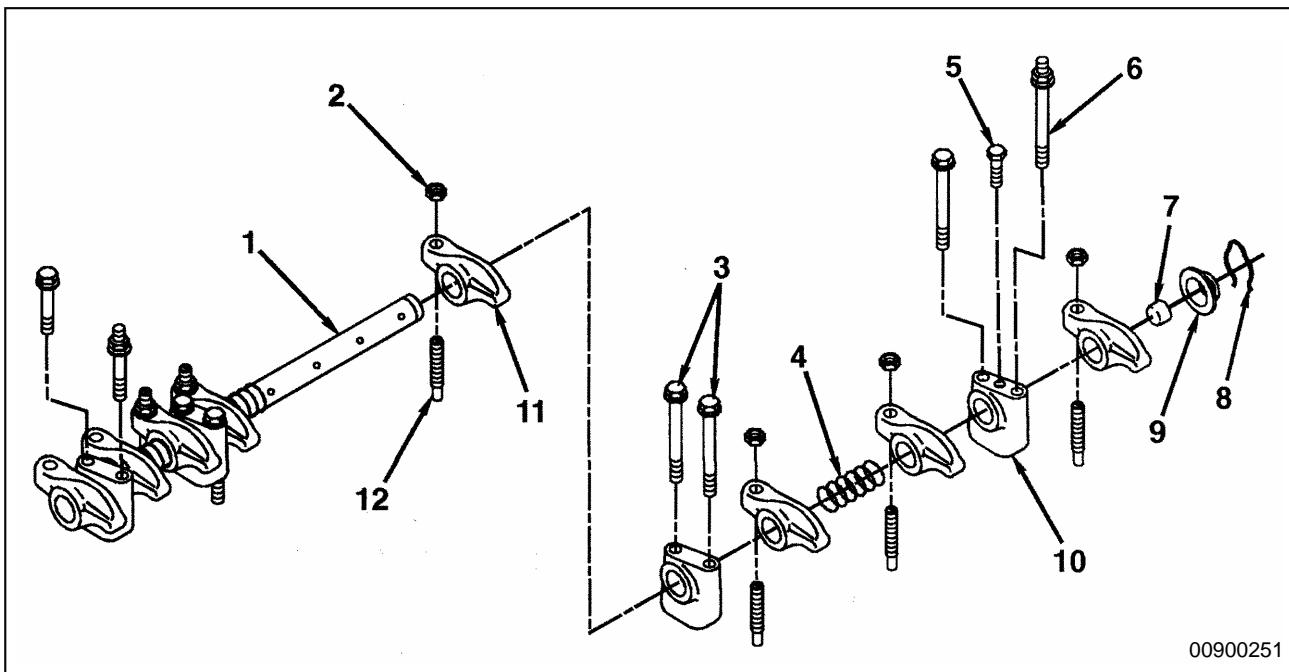
NOTE: When removing the injector, clean around the injector, and insert a blind plug to prevent dust or dirt from entering the engine.

NOTE: Mark the injectors with tags showing the cylinder number, and keep it in a safe place. If there is no abnormality in the injector, install it in the same position during assembly.



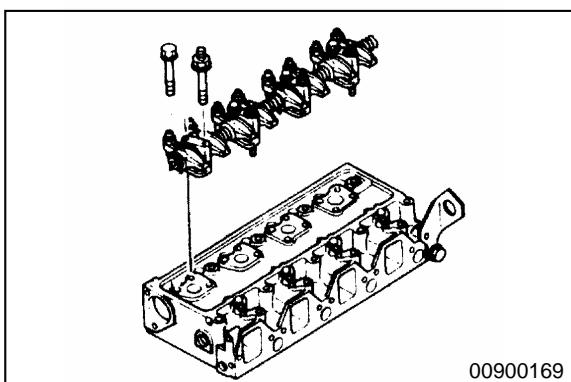
Rocker Lever Cover

Remove the three capscrews, isolator assemblies, rocker lever cover, and o-ring.



Rocker Arm Assembly

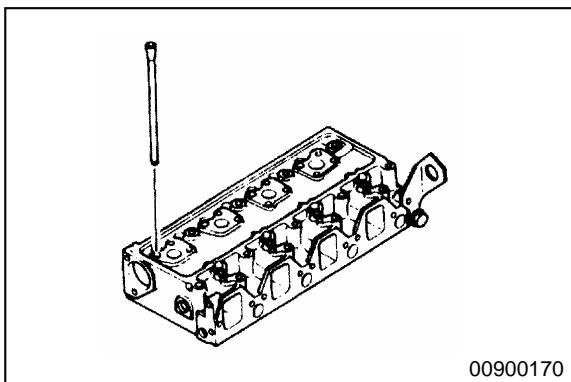
1. Rocker Shaft	7. Cup Plug
2. Adjusting Screw Lock Nut	8. Snap Ring
3. Pedestal Mounting Capscrews	9. Thrust Washer (if equipped)
4. Separating Spring	10. Rocker Lever Pedestal
5. Rocker Shaft Indexing Screw	11. Rocker Lever
6. Pedestal Mounting Stud	12. Adjusting Screw.



Rocker Arm Assembly

Remove the mounting capscrews and the rocker arm assembly.

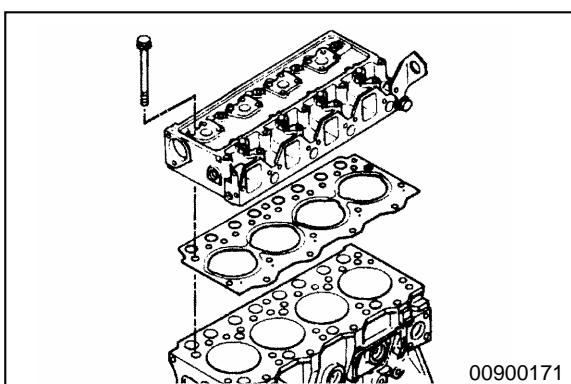
NOTE: When removing the rocker arm, loosen the locknut, and turn the adjustment screw **counterclockwise** 2 to 3 turns.



Pushrods

Remove the pushrods from the cylinder head.

NOTE: Mark the pushrods with tags showing the cylinder number, and keep it in a safe place. If there is no abnormality in the push rod, install it in the same position during assembly.



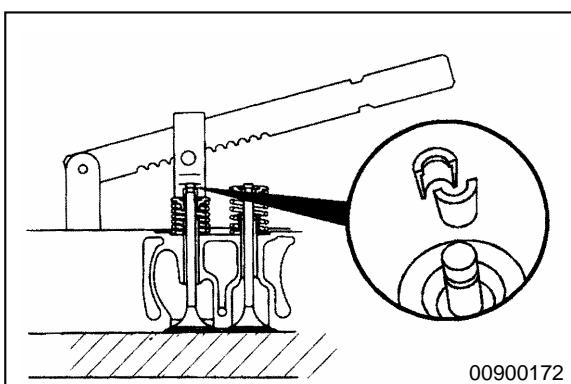
Cylinder Head Assembly

WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

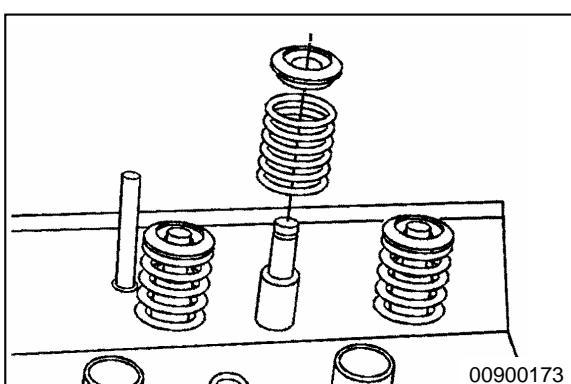
Remove the mounting capscrews, cylinder head assembly, and gasket.

Discard the gasket.

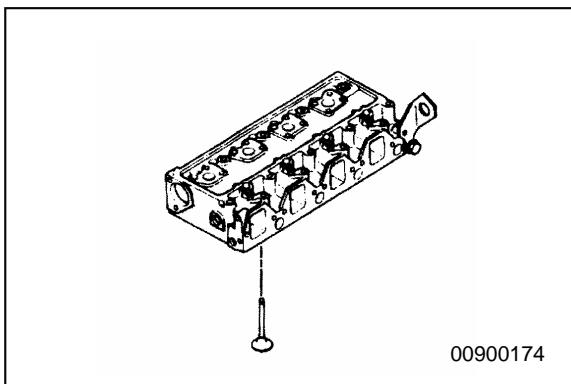


Cylinder Head Assembly - Disassembly

Using the spring pusher, Part No. 3398179, compress the valve spring, and remove the valve collets.

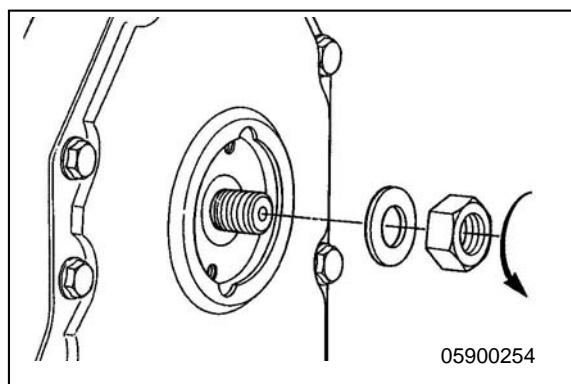


Loosen the spring, and remove the spring seat and valve spring.



Raise the cylinder head, and remove the valve.

NOTE: Mark the valves with tags to show the place of installation and keep in a safe place.



Fuel Injection Pump, Rotary

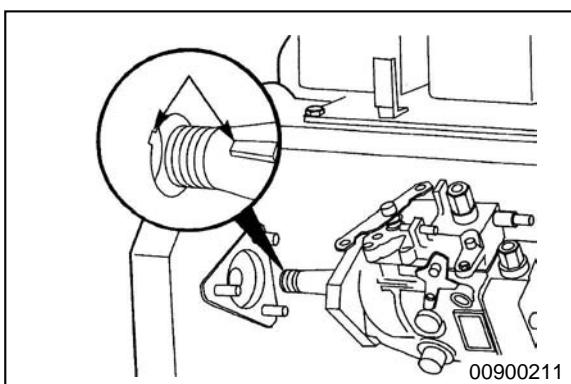
CAUTION

Do not drop the nut, washer, or key. Failure to do so will result in the need to remove the front gear cover.

Remove the gear cover access cap.

Rotate the engine until the keyway is vertical.

Remove the nut and washer from the fuel injection pump shaft.

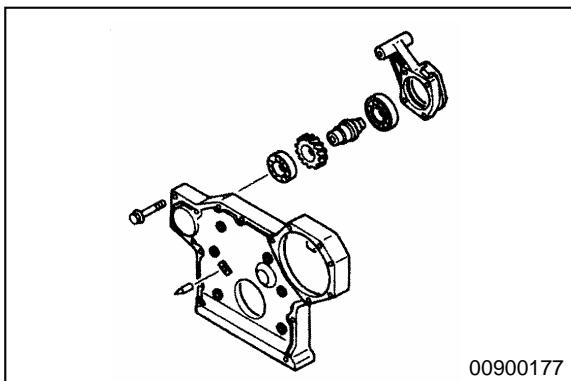


Remove the injection pump support bracket.

Remove the two mounting capscrews.

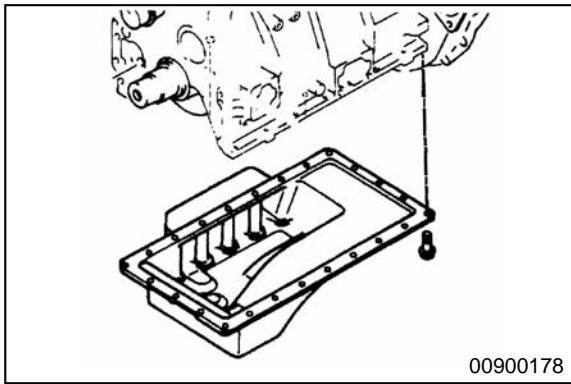
Remove the fuel injection pump.

Remove the key.



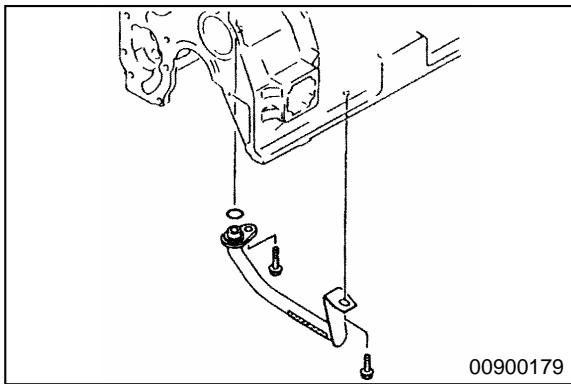
PTO Shaft (if applicable)

Remove the two capscrews, flange, o-ring, and PTO shaft.



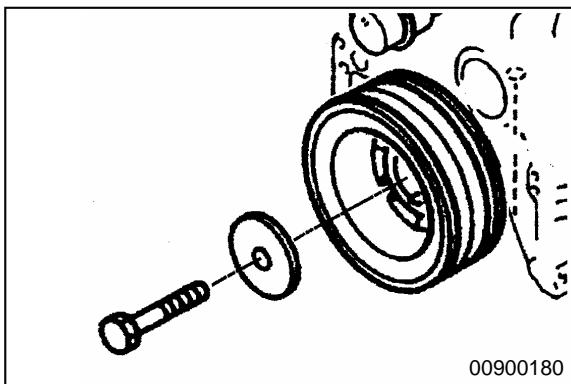
Lubricating Oil Pan

Remove the 24 capscrews, lubricating oil pan, and gasket.
Discard the gasket.



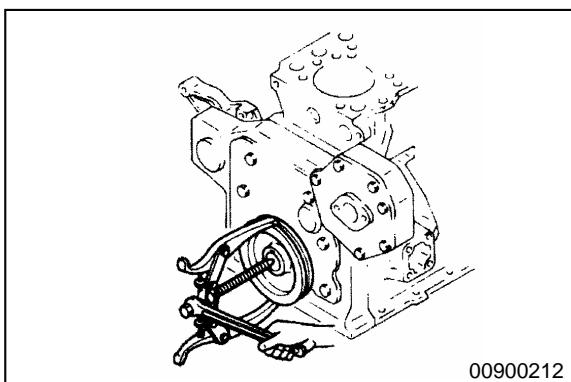
Lubricating Oil Suction Tube

Remove the two mounting capscrews, lubricating oil suction tube, and o-ring.
Discard the o-ring.

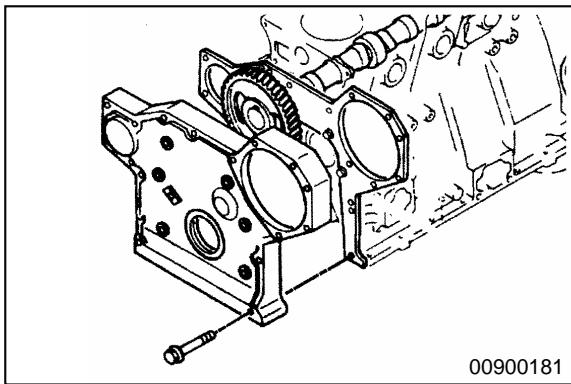


Crankshaft Pulley

Remove the capscrew and mounting plate.

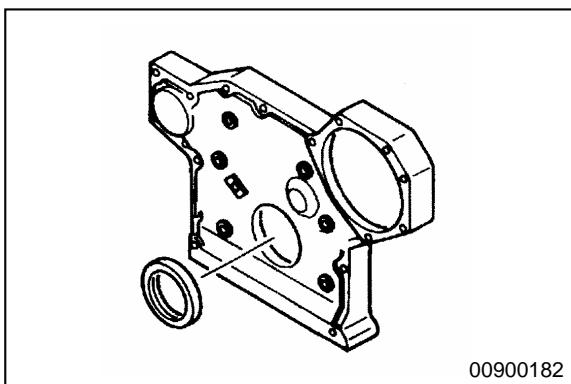


Remove the crankshaft pulley using flange puller, Part No. 3397890.



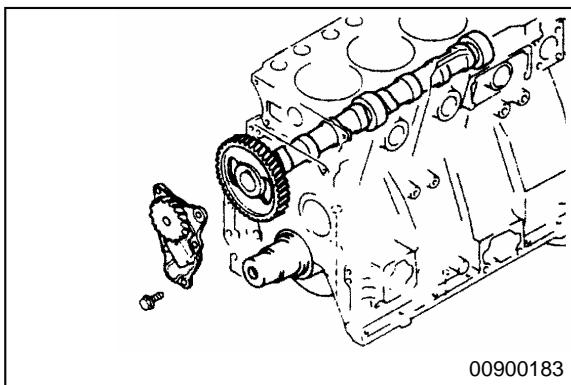
Gear Housing Cover

Remove the 17 capscrews and the gear housing cover.



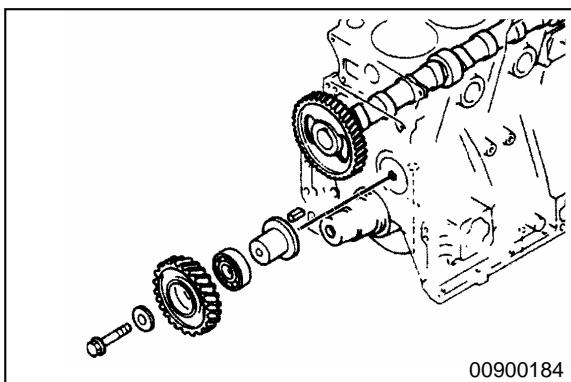
NOTE: A noise damper is installed on some engines. The noise damper **must** be removed prior to removing the front oil seal.

Remove the front oil seal from the gear housing cover.



Lubricating Oil Pump

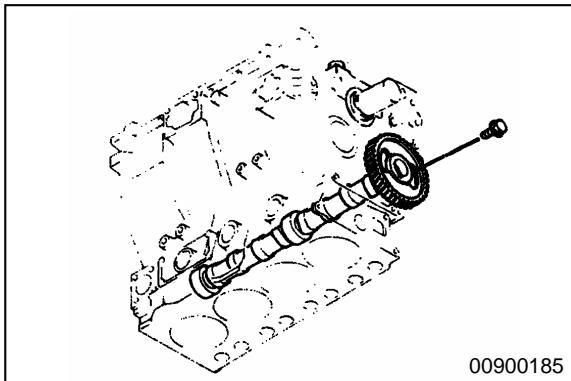
Remove the five capscrews and the lubricating oil pump.



Idler Gear

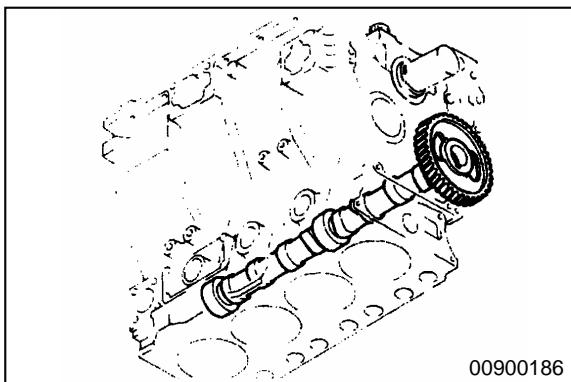
Remove the capscrew, retainer plate, and idler gear.

NOTE: If a PTO is installed, the idler gear uses a bearing.



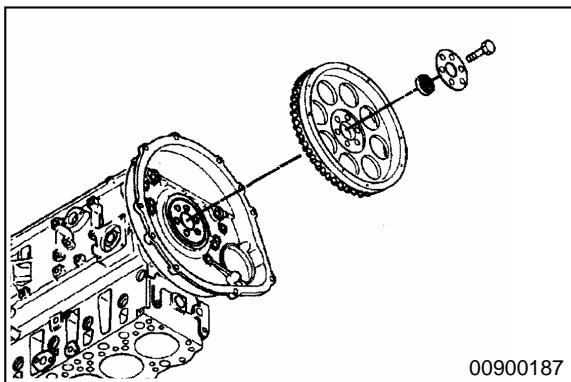
Camshaft Assembly

Remove the two mounting capscrews through the casting holes in the camshaft gear.



Remove the thrust plate and camshaft assembly.

NOTE: When removing the camshaft, lightly rotate the shaft while being careful **not** to damage the bushing.



Flywheel

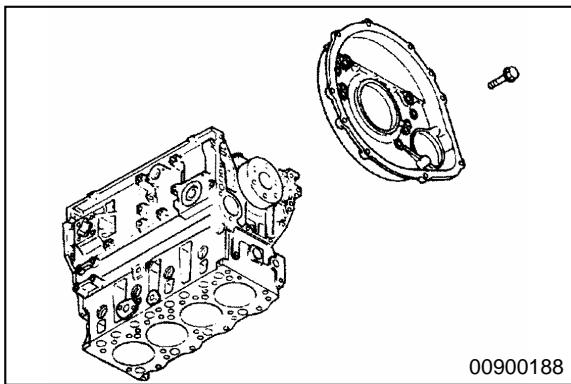
⚠ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

⚠ WARNING

The pilot is short, so the flywheel can come off suddenly.

Remove the six capscrews, retaining plate, coupling, and flywheel.

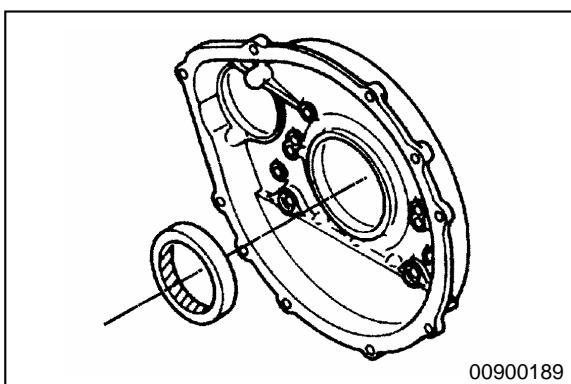


Flywheel Housing

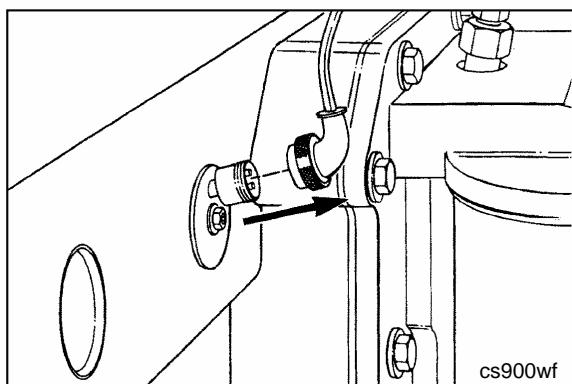
⚠️ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

Remove the nine capscrews, rear oil seal, and flywheel housing.



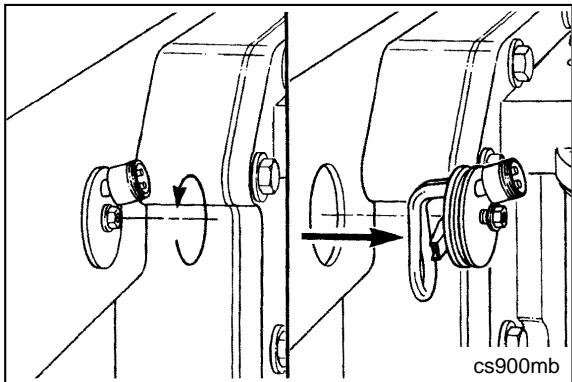
Remove the rear oil seal.



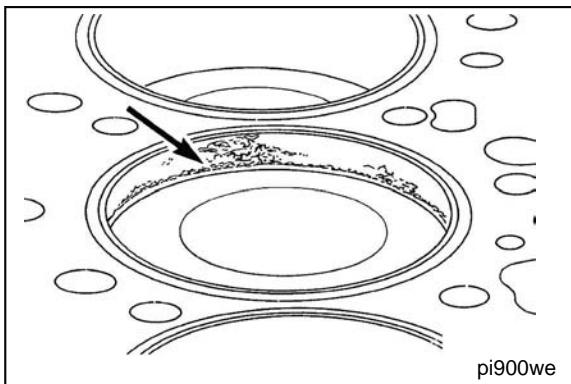
Block Water Heater

NOTE: Be sure the engine coolant has been drained.

Disconnect the block heater electrical cord.



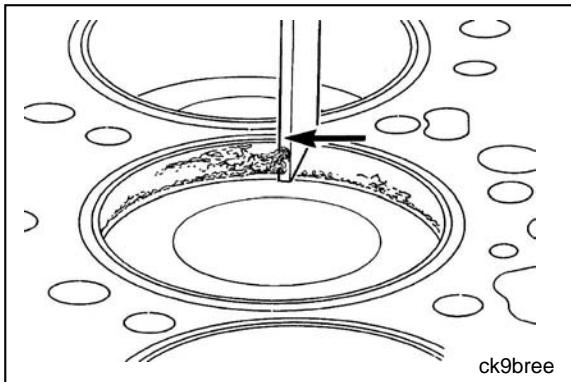
Loosen the block heater retaining nut.
Remove the block heater from the block.



Piston, Connecting Rod Assembly

Remove

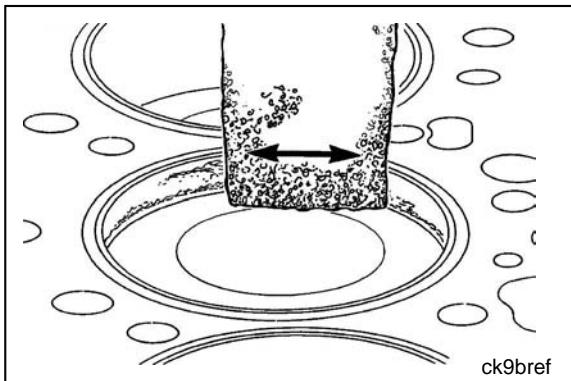
Rotate the crankshaft with an engine barring tool until the pistons are below the carbon deposits, which are found above the ring travel area.



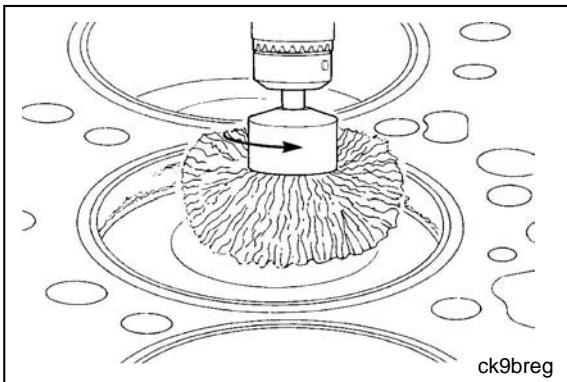
CAUTION

Do not use emery cloth or sandpaper to remove carbon from the cylinder bores. Aluminum oxide or silicon particles from these materials can cause serious engine damage.

Use a scraper or a blunt-edged instrument to loosen the carbon deposits. Do not damage the cylinder with the scraper.



Remove the remaining carbon deposits with an abrasive pad, Part Number 3823258, or equivalent.



⚠ WARNING

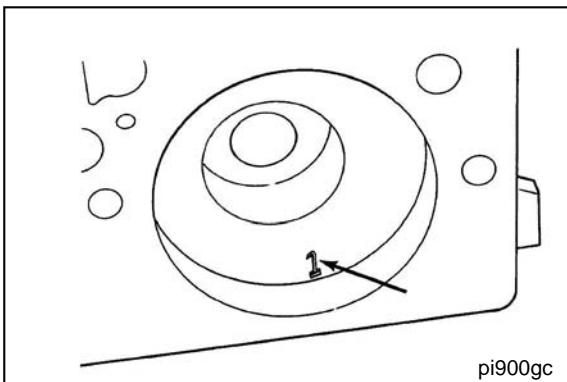
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

⚠ CAUTION

Do not use the steel wire wheel in the piston travel area. Operate the wheel in a circular motion to remove the deposits.

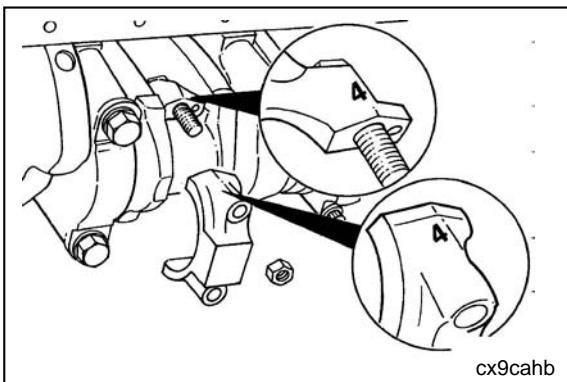
NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

An alternative method to remove the carbon ridge is to use a high-quality steel wire wheel installed in a drill or die grinder.



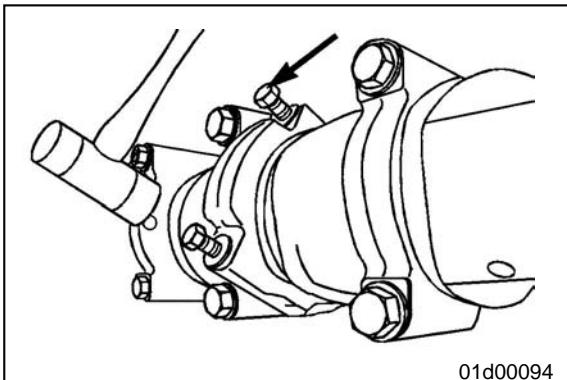
On pistons with anodized coatings, do not stamp the anodized coating on the outer rim.

Mark each piston according to the cylinder location



Rotate the crankshaft to position the connecting rod caps at bottom dead center for removal.

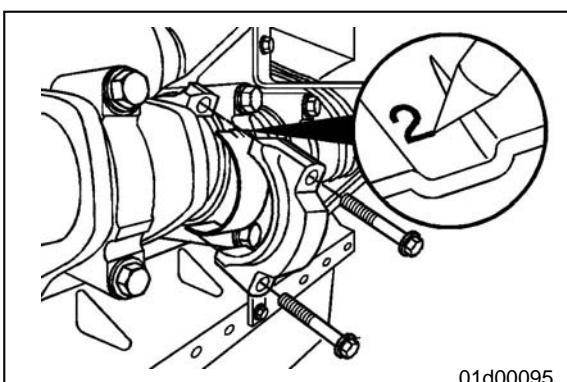
Mark each connecting rod and connecting rod cap according to the cylinder number location.



NOTE: Do not remove the capscrews from the connecting rods at this time.

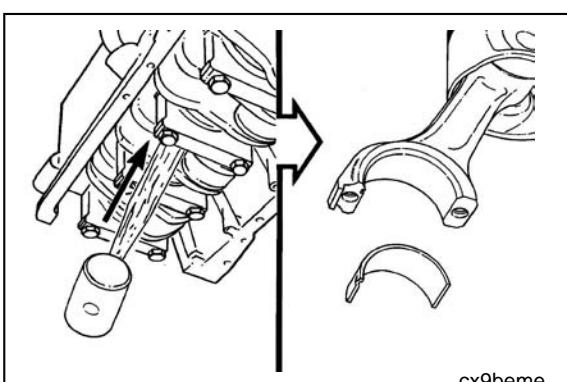
Loosen the connecting rod capscrews.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.



Remove the connecting rod capscrews.

Remove the connecting rod cap.

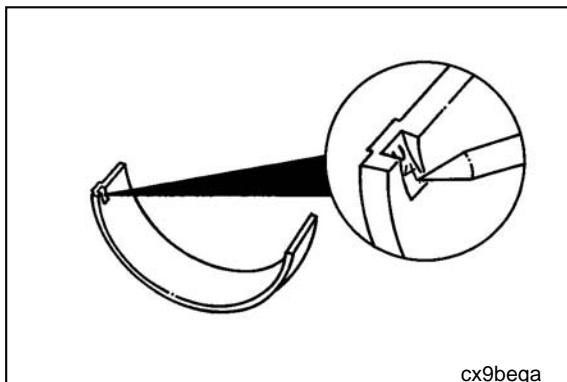


Remove the lower connecting rod bearing.

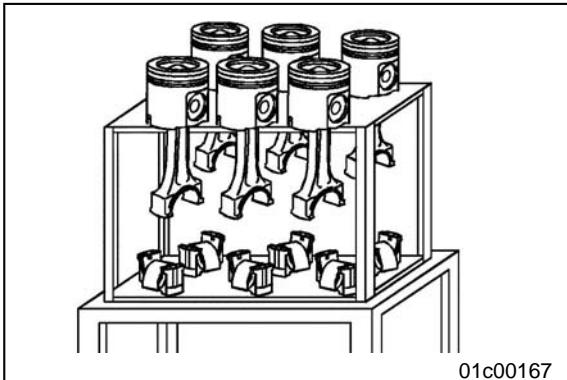
Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.

Push the connecting rod and piston assembly out of the cylinder bore. Care must be taken not to damage the connecting rod or bearing.

Remove the upper rod bearing.



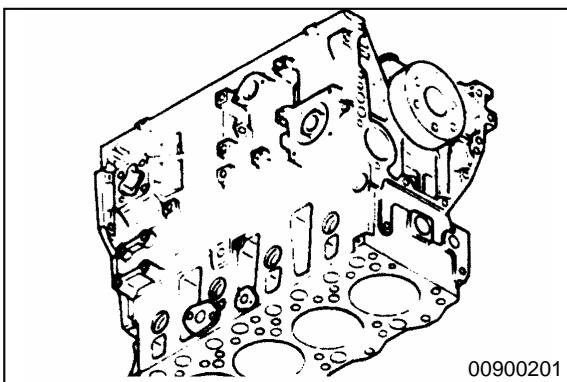
Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.



The piston and connecting rod assemblies must be installed in the same cylinder number from which they were removed, to provide proper fit of worn mating surfaces, if parts are reused.

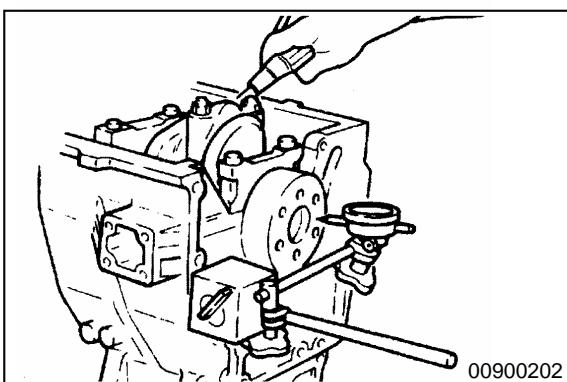
Use a tag to mark the cylinder number from which each piston and rod assembly were removed.

Place the rod and piston assemblies in a container to protect them from damage.



Main Bearing Cap

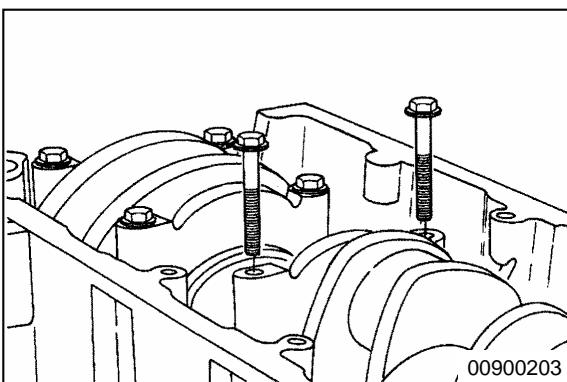
Rotate the cylinder block so that the bottom of the block is facing up.



Measure the end play of the crankshaft using a dial gauge.

NOTE: The end play measurement is necessary for determining the wear of the thrust bearing and abnormal wear of the crankshaft.

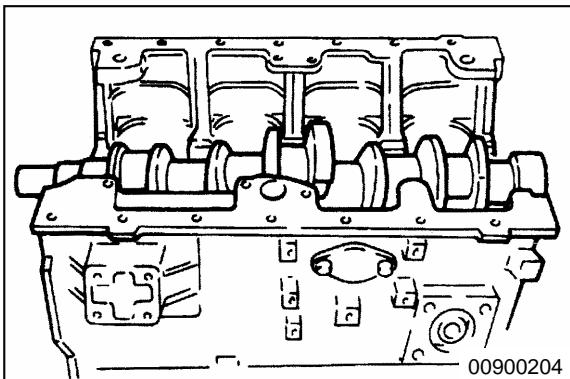
Crankshaft End Play		
mm		in
0.131	MIN	0.0052
0.351	MAX	0.0138



Remove the mounting capscrews of the main bearing cap.

Remove the main bearing cap and lower bearing.

NOTE: Mark the thrust bearings so that they can be installed into the correct position. The main bearing cap mounting capscrews **must** be replaced after each use.

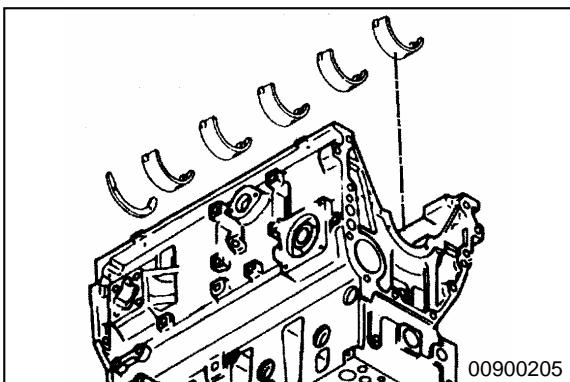


Crankshaft

⚠ CAUTION

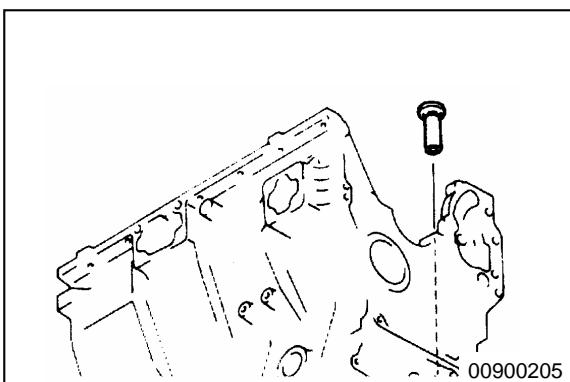
Be careful not to hit the crankshaft against the cylinder block and damage the sliding surface.

Remove the crankshaft.



Remove the upper main bearing.

NOTE: Mark the main bearings and thrust bearing so that they can be installed into the correct position.



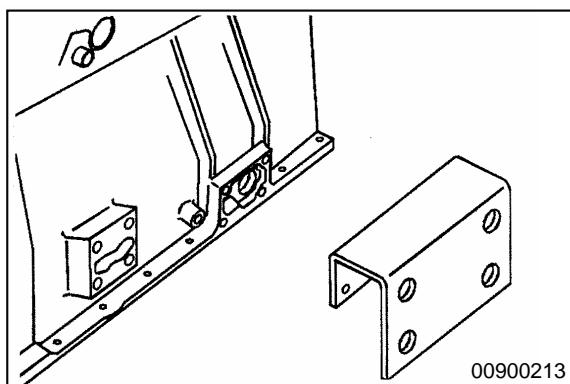
Tappet

Remove the tappet.

Engine Assembly

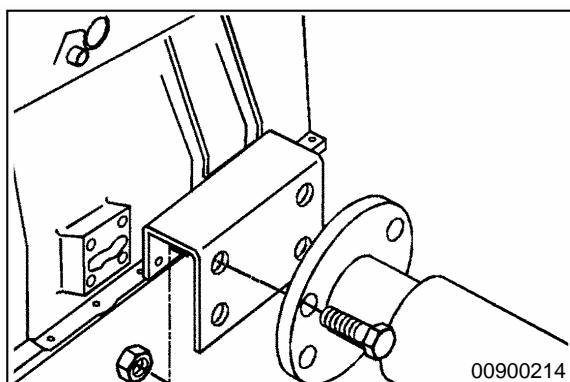
Service Tools

Part No.	Part Name	Quantity
3375193 or 3375194	Unit Repair Stand or Engine Overhaul Stand	1
3163625	Bracket	1
3163292	Valve Spring Compressor	1
3823137	Piston Ring Expansion Tool	1
3397773	Piston Ring Compressor	1



Setting the Unit in the Repair Stand

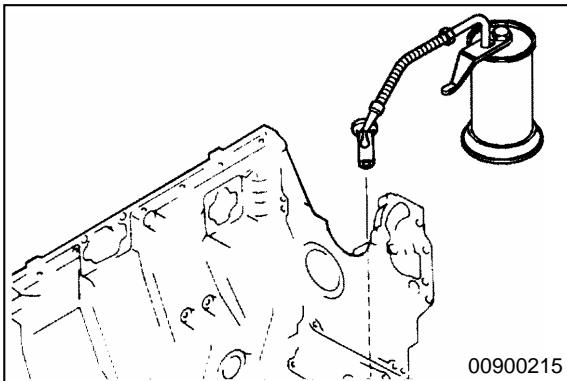
Install bracket, Part No. 3163625, to the cylinder block.



WARNING

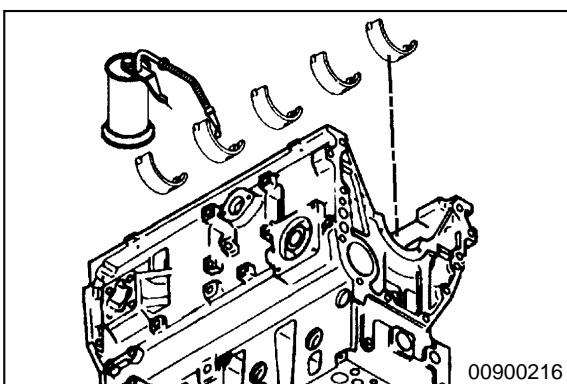
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Put the engine block on the stand.



Tappet

NOTE: Rotate the engine block so that the cylinder head side is down.
Coat the tappet with engine oil and install into the block.



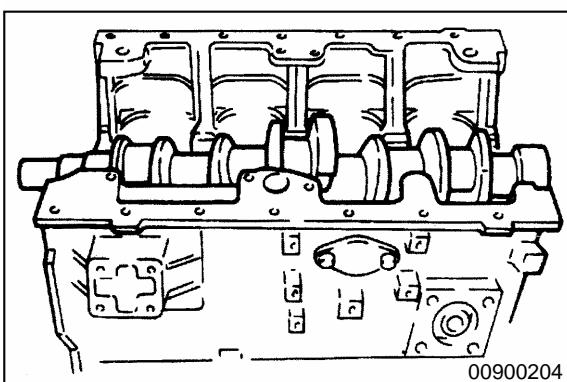
Crankshaft

⚠ CAUTION

Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Debris behind the bearing can cause severe engine damage.

NOTE: Coat the inside face of the bearing with engine oil (SAE 30) before installation.
Align the protrusion of the upper main bearing with the notch in the cylinder block.

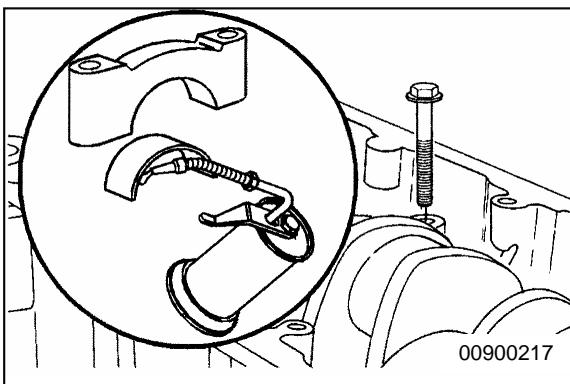
Install the upper main bearings.



⚠ CAUTION

Do not hit the crankshaft against the cylinder block. Damage to the block or crankshaft can occur.

Position the crankshaft and gear in the cylinder block.



Main Bearing Cap

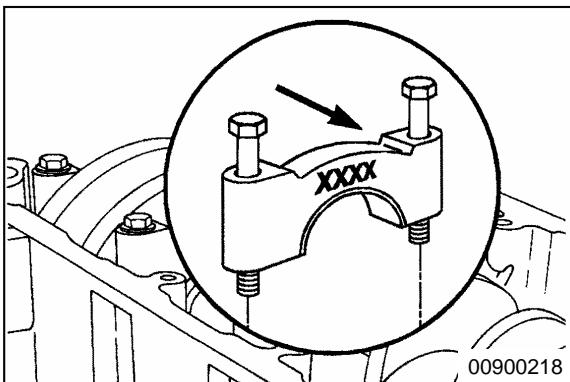
CAUTION

Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Debris behind the bearing can cause severe engine damage.

NOTE: Coat the inside face of the bearing with engine oil (SAE 30) before installation. The number stamped on the main bearing cap must be the same as the number stamped on the cylinder block.

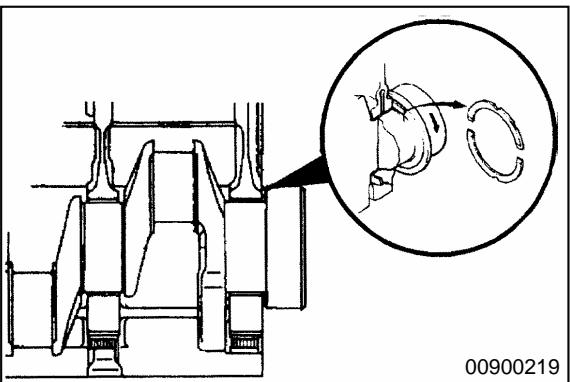
Align the protrusion in the lower main bearing with the notch in the cap.

Install the lower main bearing into the main bearing cap.



- Casting number or cast arrow on the main bearing cap must face toward the front of the engine.
- New main bearing mounting capscrews must be used.
- Coat the capscrew threads and seat face with engine oil.

Position the main bearing caps and capscrews.



CAUTION

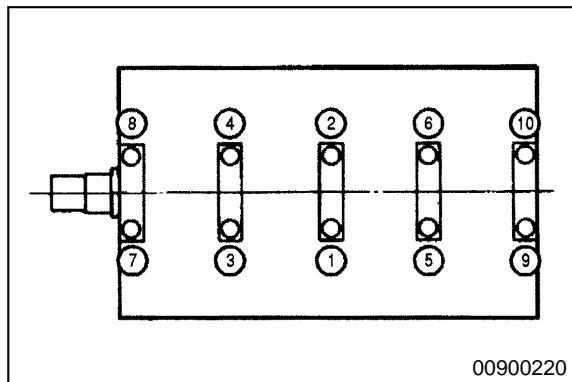
Install each thrust bearing with the oil groove on the outside. Failure to do so will cause engine damage or failure.

CAUTION

Do not let the thrust bearings slip out of place. Engine damage or failure will result if the thrust bearings are not properly installed.

NOTE: Casting number or cast arrow on the main bearing cap **must** face toward the front of the engine. The thrust bearing is located on the main bearing closest to the rear of the engine (No. 5). Align the lower thrust bearing with the dowel pin.

Install the upper thrust bearing.



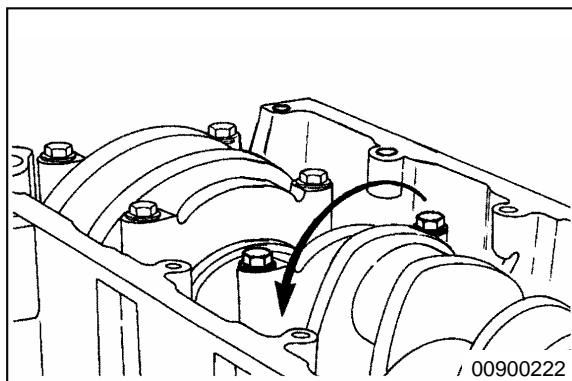
Tighten the mounting capscrews in the order shown.



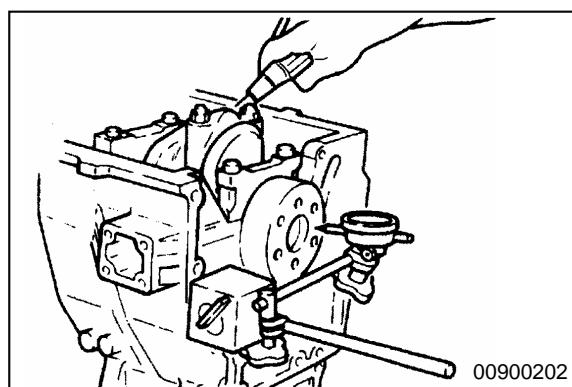
Torque Value:

Main Bearing
Capscrews

Step 1 113 N·m [83 ft-lb]
2 Loosen all capscrews
completely
3 132 N·m [98 ft-lb]

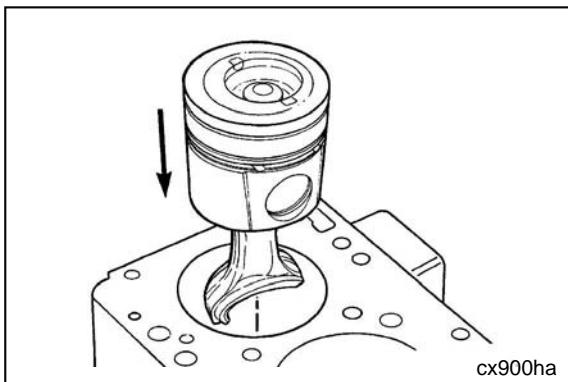


After tightening the mounting capscrews, make sure the crankshaft rotates smoothly



Measure the crankshaft end play using a dial indicator.

Crankshaft End Play		
mm		in
0.131	MIN	0.0052
0.351	MAX	0.0138



Piston, and Connecting Rod Assembly

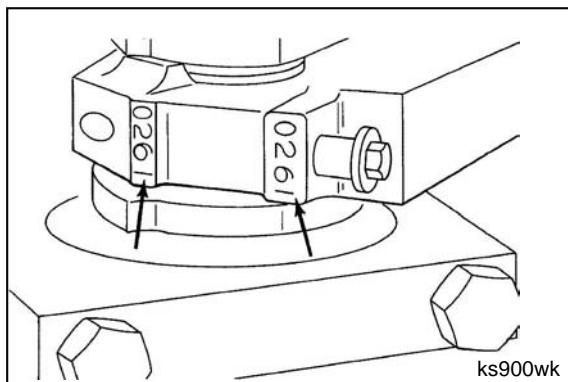


When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in their original cylinders.

If replacing the piston(s), make sure the replacement piston(s) are the same grade as the original piston(s).

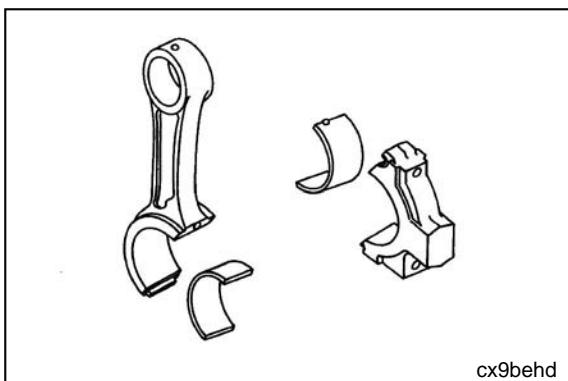
If a new cylinder block or crankshaft is used, the piston grading procedure must be performed to determine the proper piston grade for each cylinder.

Install the connecting rod and piston assembly into the Number 1 cylinder without the rings installed.



The number stamped on the connecting rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

Install the connecting rod cap and capscrews to the connecting rod.



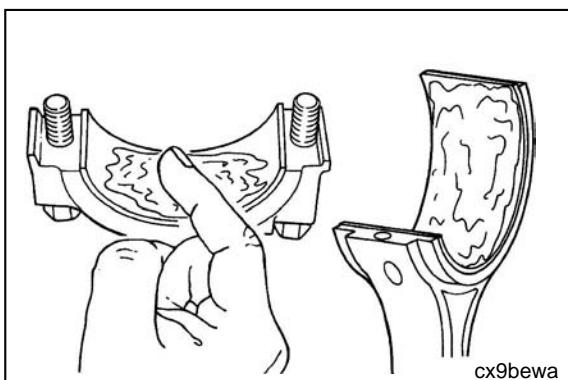
⚠ CAUTION



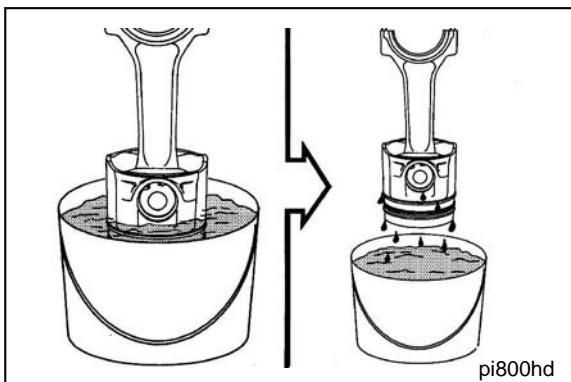
The connecting rods and connecting rod caps are not interchangeable. The connecting rods and connecting rod caps are machined as an assembly. Failure will result if the connecting rods and caps are mixed.

Install the bearing shells into both the connecting rod and the connecting rod cap.

Make sure the tang on the bearing shells is in the slot of the connecting rod cap and connecting rod.

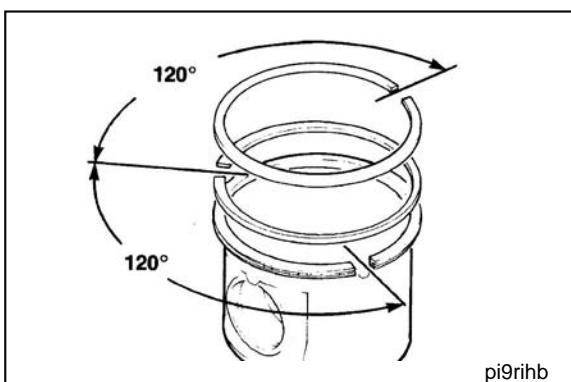


Lubricate the connecting rod bearings with clean lubricating engine oil.

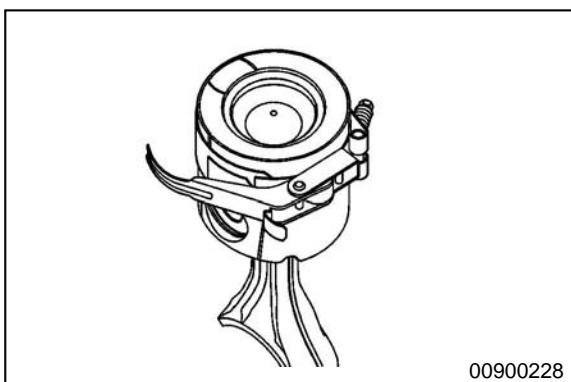


Immerse the pistons in clean 15W-40 engine lubricating oil until the rings are covered.

Allow the excess oil to drip off the assembly.



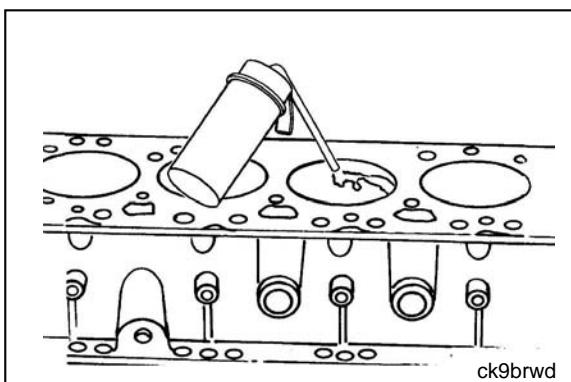
Position the rings so that the ring gaps are 120 degrees apart.



⚠ CAUTION

If using a strap type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

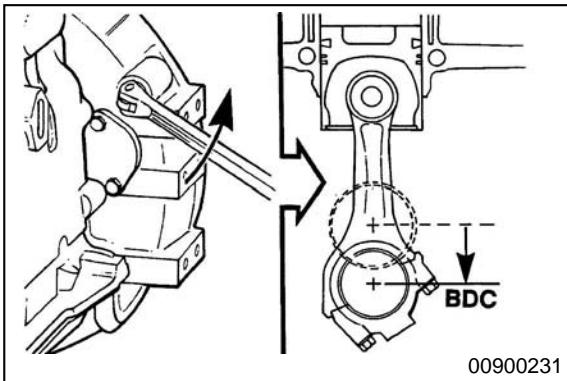
Use piston ring compressor, Part Number 3164330, or equivalent, to compress the rings.



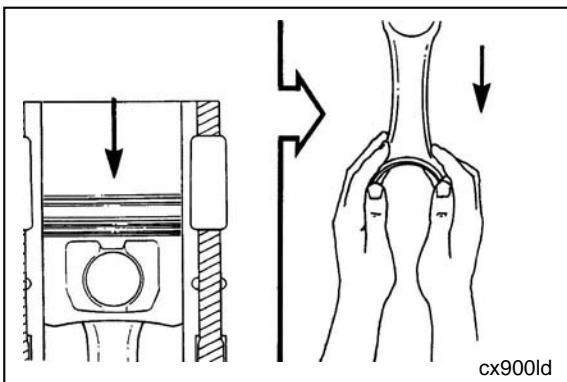
Lubricate the cylinder bore with clean 15W-40 engine lubricating oil.

The cylinder block must be clean before assembly.

Inspect the cylinder bores for reuse.



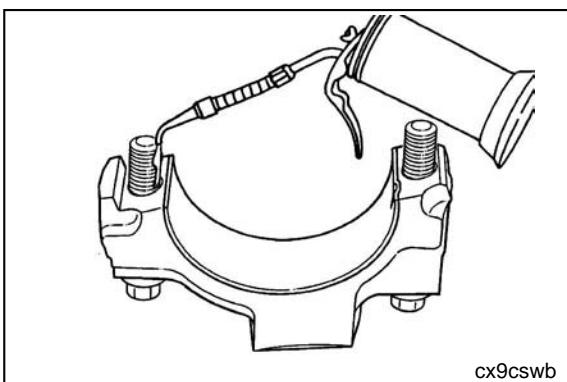
Position the connecting rod journal for the piston to be installed to bottom dead center (BDC).



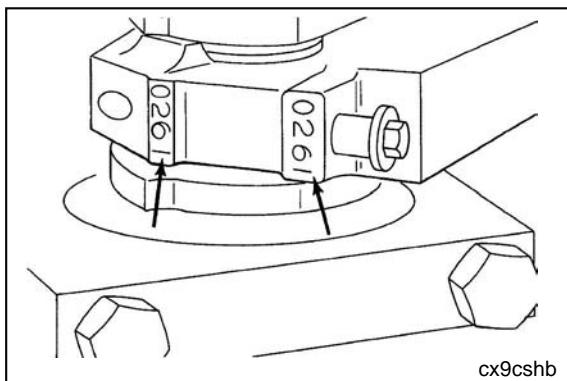
Take care to not damage the cylinder wall when inserting the connecting rod.



Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.



Lubricate the threads and underside of the connecting rod capscrew heads with clean 15W-40 lubricating engine oil.



⚠️ WARNING

The number stamped on the rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

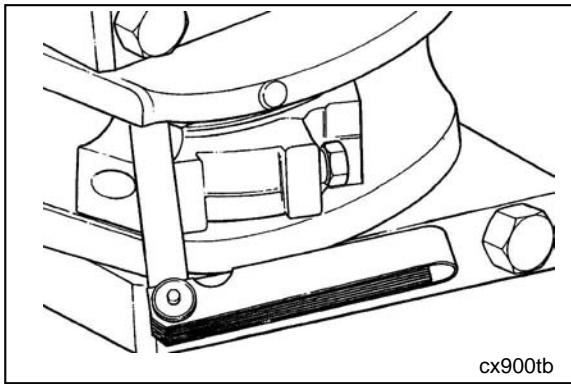
Install the connecting rod cap and capscrews.

Tighten the two capscrews in alternating sequence.

Torque Value:

Step 1 39 n.m [29 ft-lb]

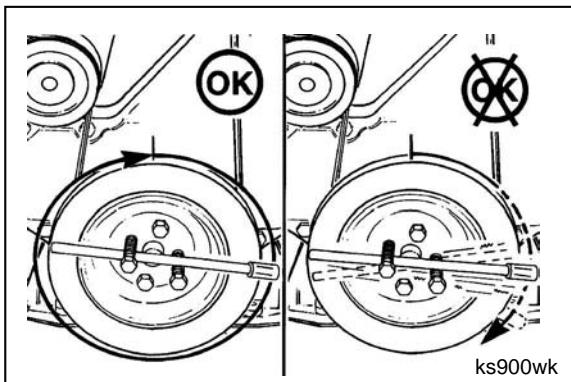
Step 2 Rotate each capscrew 90 degrees.



Do not measure the clearance between the connecting rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Connecting Rod Cap Side Clearance		
Mm	in	
0.20	MIN	0.0079
0.40	MAX	0.0160



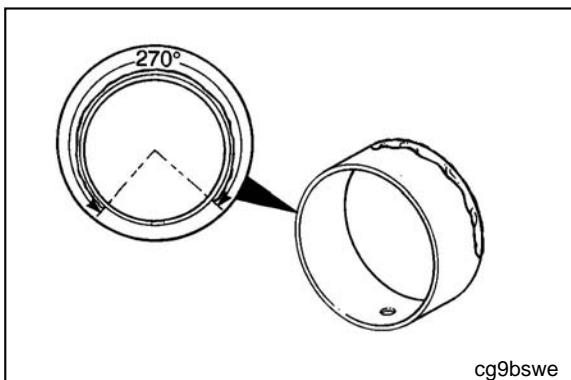
⚠ CAUTION

To reduce the possibility of engine damage, the crankshaft must rotate freely.



If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.

If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.

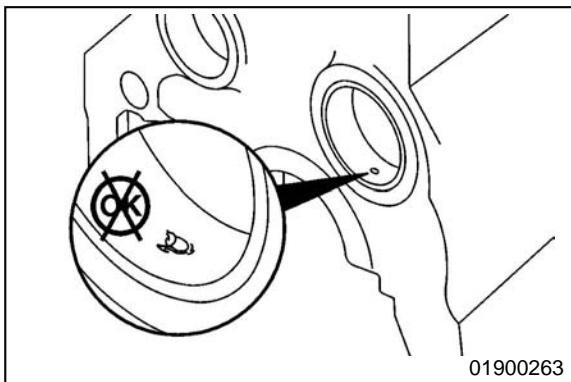


Camshaft Bushings

Apply Loctite primer to the outside diameter of the camshaft bushing and the inside of the camshaft bore of the cylinder block.

Allow the primer to dry.

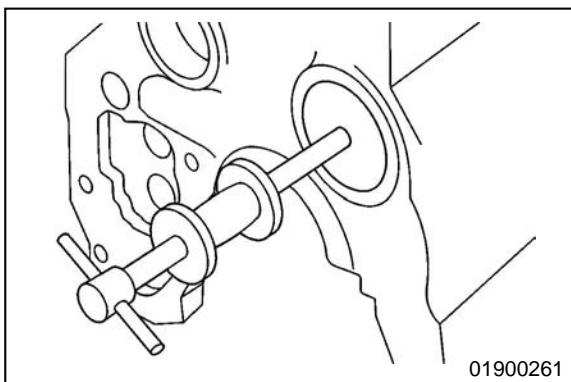
Apply a bead of Loctite 609, or equivalent, to 270 degrees along the edge of the bushing that will be installed toward the rear of the cylinder block.



⚠ CAUTION

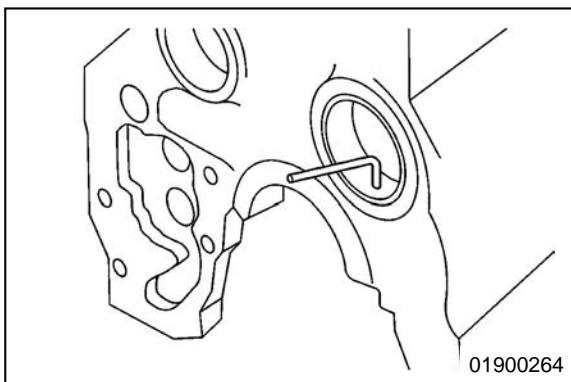
Make sure there is no Loctite in the oil hole, or severe engine damage can occur.

Use extreme care not to apply Loctite to the oil hole in the camshaft bushing.



Use a small camshaft bushing driver set, Part Number 3823942, or equivalent, to install the camshaft bushing even with the front face of the cylinder block.

Use a clean, lint-free cloth to wipe off any excessive Loctite.

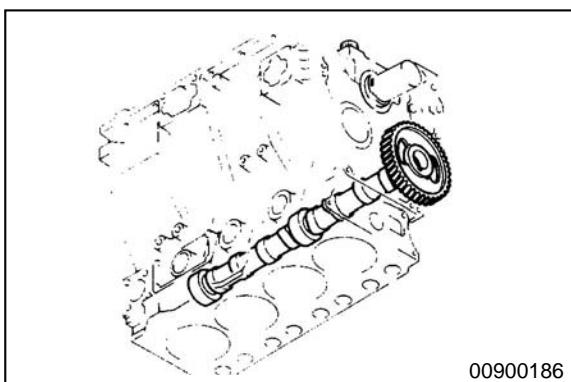


⚠ CAUTION

Make sure there is no Loctite in the oil hole, or severe engine damage can occur.

Make sure the lubricating oil hole in the camshaft bushing is aligned with the camshaft oil hole in the cylinder block.

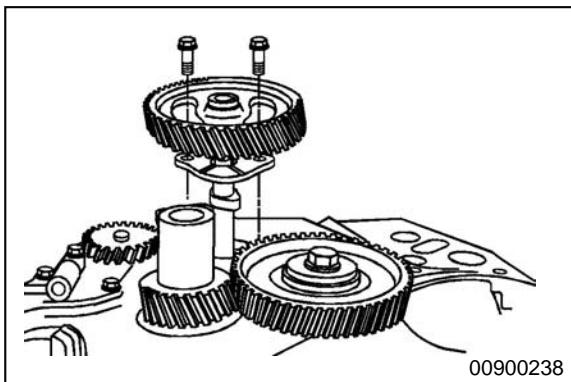
A 3.2-mm [0.126-in] diameter rod must be able to pass through the lubricating oil hole.



Camshaft

Thrust Bearing

Install the thrust bearing.



Camshaft

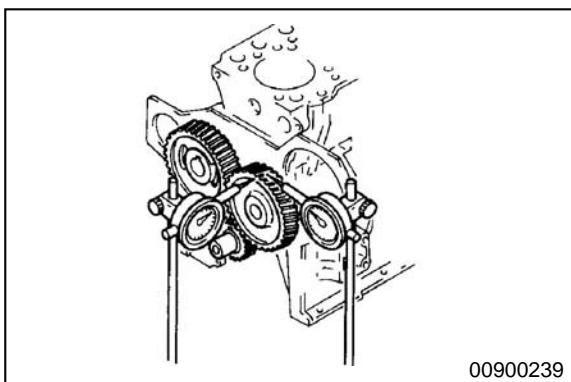
Install

NOTE: When installing the camshaft, rotate the camshaft slightly while being careful not to damage the bushing.

Install the thrust plate, camshaft assembly, and two capscrews.

Tighten the capscrews through the casting holes in the camshaft gear.

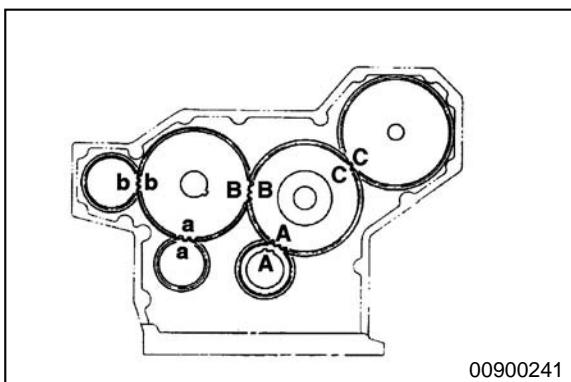
Torque Value: 19 N·m [14 ft-lb]



Measure the end play of the camshaft.

Camshaft End Play

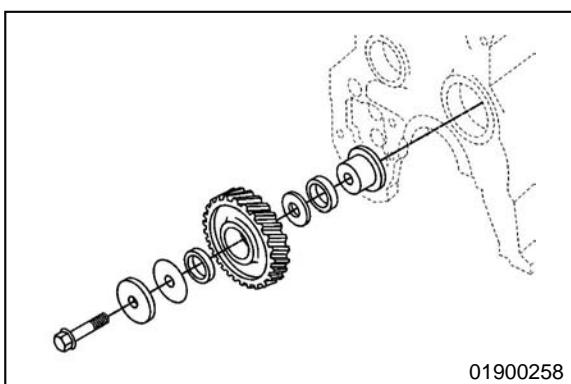
mm	in
0.150	MIN 0.0059
0.350	MAX 0.0138



Idler Gear, Camshaft

Align the match marks of the idler gear, crankshaft gear, and camshaft gear. The match marks are identified as follows:

- Crankshaft Gear and Idler Gear: **A**
- Idler Gear and Camshaft Gear: **B**
- Fuel Pump and Idler Gear: **C**
- Lower case letters identify oil pump and accessory drive, which are **not** timed.

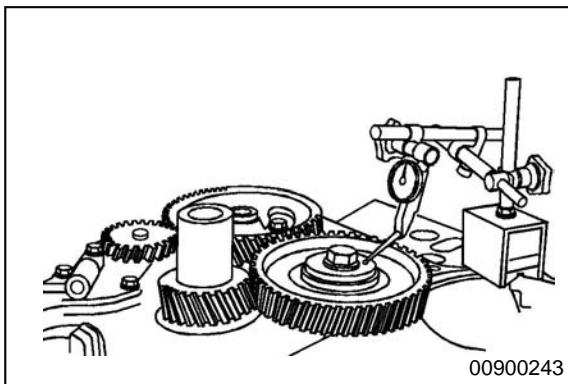


If a PTO accessory drive is used on the engine, the idler gear uses two bearings.

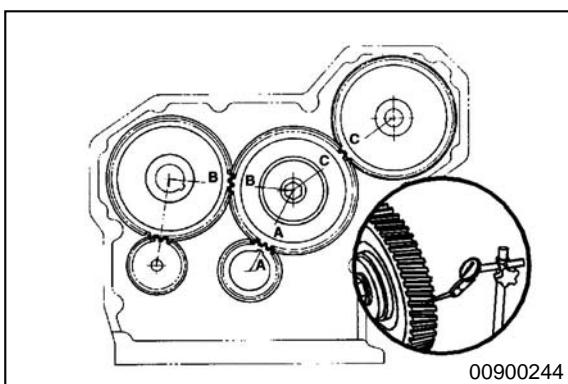
Install the idler shaft, rear bearing, rear spacer plate, and idler gear.

Install the front bearing, plate, shim, and capscrew. Tighten the capscrew.

Torque Value: 110 N·m [81ft-lb]



Measure the end play of the idler gear.



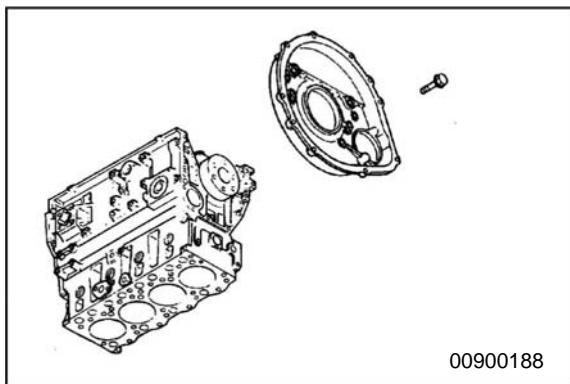
Position the fuel injection pump assembly temporarily.



Measure the backlash of each gear with a dial indicator, 3376050, or equivalent.

Match mark alignment:

			Naturally Aspirated	
Backlash	A	Crankshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in]	Replacement Limit: 0.40 mm [0.0157 in]
	B	Camshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in] Aspirated	
	C	Injection pump gear and idler gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
	a	Camshaft gear and oil pump gear	0.15 mm to 0.30 mm [0.006 in to 0.012 in]	
	b	Camshaft gear and PTO gear	0.03mm to 0.050mm [0.0012 in 0.0035 in]	
Clearance Between Bushing and Shaft			0.015 mm to 0.050 mm [0.0006 in to 0.002 in]	Replacement Limit: 0.10 mm [0.0039 in]
End Play of Idler Gear			0.03 mm to 0.09 mm [0.0012 in to 0.0035 in]	Replacement Limit: 0.20 mm [0.0079 in]



Fly Wheel Housing

NOTE: Make sure the crankshaft oil seal is not damaged during installation.

Lubricate the crankshaft oil seal with Lubriplate™ 105, or equivalent.

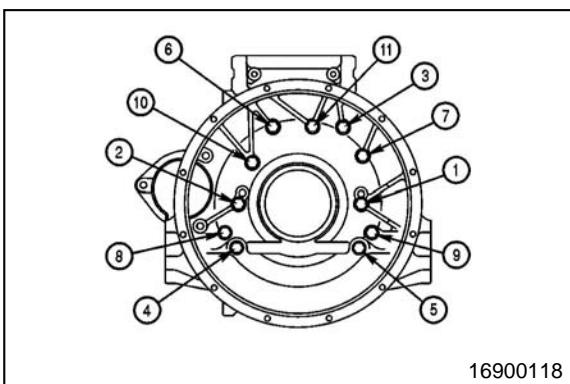


Install the crankshaft oil seal into the flywheel housing.



Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

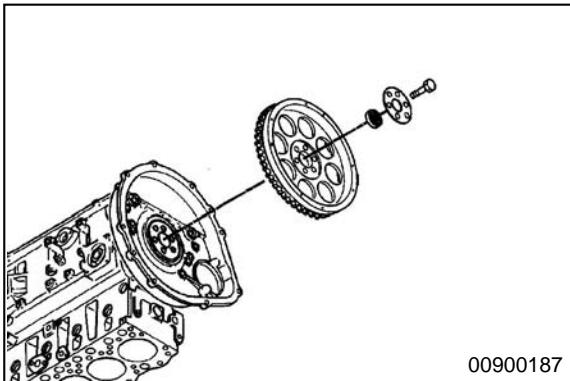
Install the flywheel housing over the two dowel pins.



Tighten the flywheel housing mounting capscrews in the sequence shown in the illustration.



Torque Value: 69 N•m [51ft-lb]



Flywheel



Install the guide pins, Part Number 3376696, or equivalent, into the empty capscrew holes 180 degrees apart.

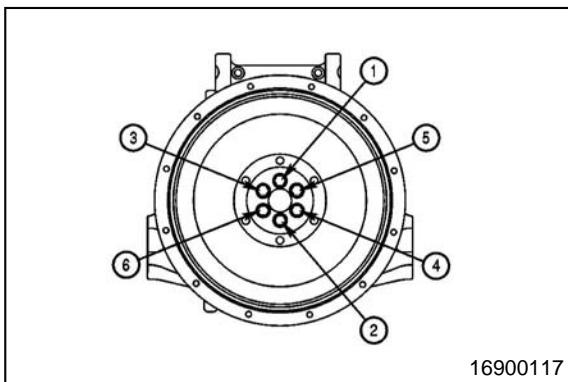


Determine the capscrew thread design and size, and install two T-handles in the flywheel 180 degrees apart on a horizontal plane.

Install the coupling, retaining plate, and flywheel. Coat all capscrews with clean lubricating engine oil.

Install four of the six mounting capscrews into the flywheel. Hand tighten.

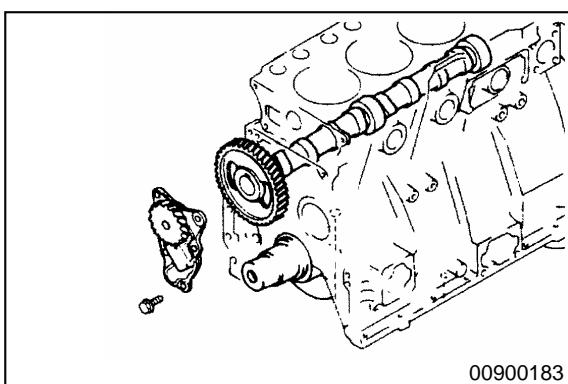
Remove the guide pins and install the remaining two mounting capscrews. Hand tighten.



Tighten the mounting capscrews in the sequence shown in the illustration.

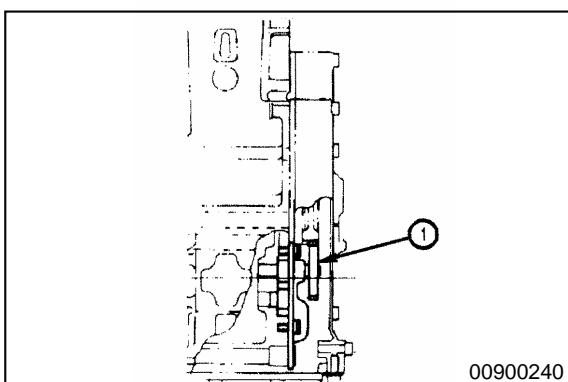


Torque Value: Step 1 108 N·m [80ft-lb]
Step 2 191 N·m [141ft-lb]



Oil Pump

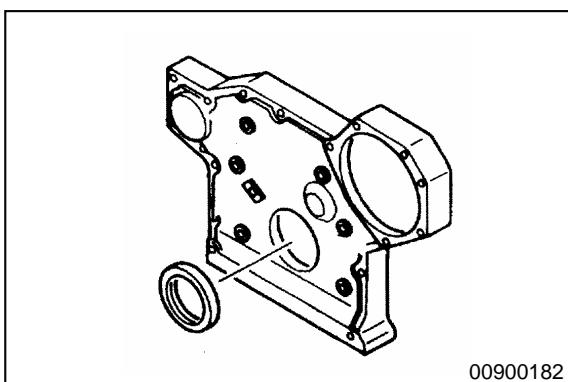
Install the lubricating oil pump and five capscrews. Tighten the capscrews.



Torque Value: 19 N·m [14 ft-lb]

Measure the end play of the lubricating oil pump drive gear.

Lubricating Oil Pump Drive Gear End Play		
mm	in	
0.020	MIN	0.0008
0.070	MAX	0.0028



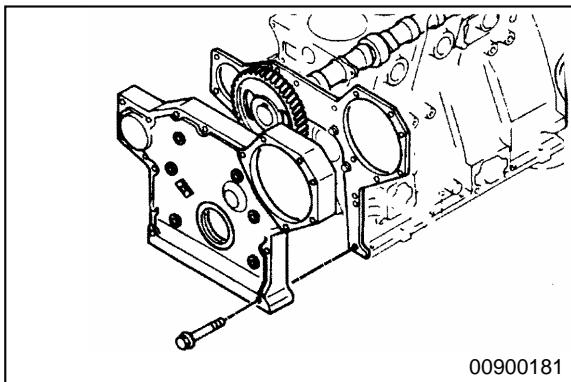
Gear Housing Cover



NOTE: A noise damper is installed on some engines. The noise damper **must** be installed prior to installing the front oil seal.

Install the front oil seal using tool, Part No. 3824498.

Fill 40 to 60 percent of the space in the seal lip with grease.



⚠ CAUTION

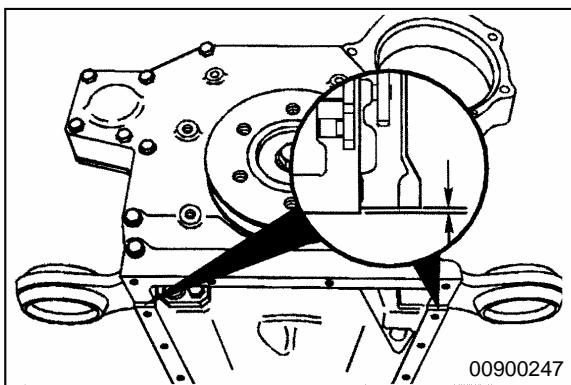


Do not apply excessive force to the seal lip surface when aligning and installing the gear housing cover. Damage to the engine will occur if the seal is damaged.

NOTE: Apply gasket sealant, Part No. 3823494, to the gear housing cover mounting surface.

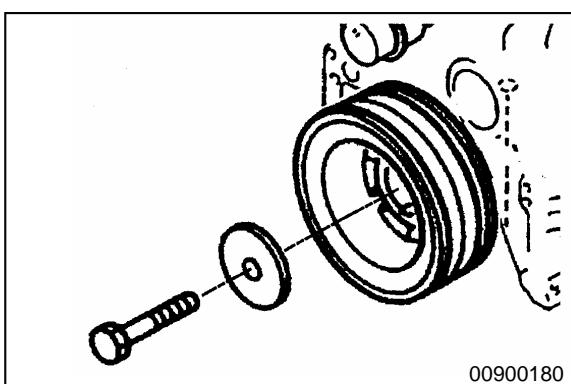
Install the gear housing cover and 17 capscrews. Tighten the capscrews.

Torque Value: 19 N·m [14 ft-lb]



Measure the distance in height between the cylinder block and the gear housing cover.

Maximum Height Difference: 0.15 mm [0.0059 in]



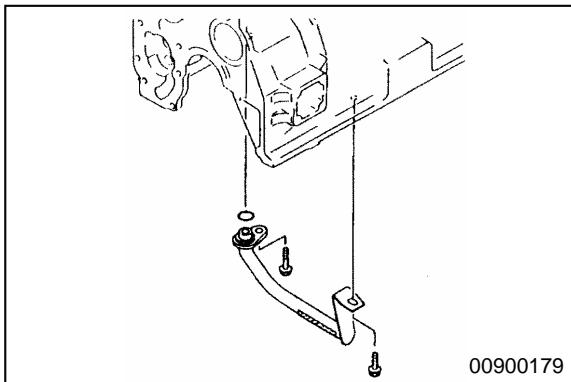
Crankshaft Pulley

Align the crankshaft pulley with the crankshaft key.

Install the crankshaft pulley, mounting plate, and capscrew.

Tighten the capscrew.

Torque Value: 93 N·m [69 ft-lb]

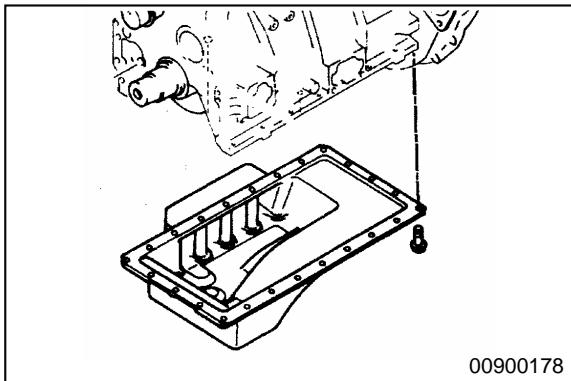


Lubricating Oil Suction Tube

Install a new o-ring, oil suction tube, and two capscrews.

Tighten the capscrews.

Torque Value: 19 N·m [14 ft-lb]



Lubricating Oil Pan



NOTE: Apply a 1-mm [0.039-in] bead of gasket sealant, Part No. 3823494, to the mounting surface of the lubricating oil pan.

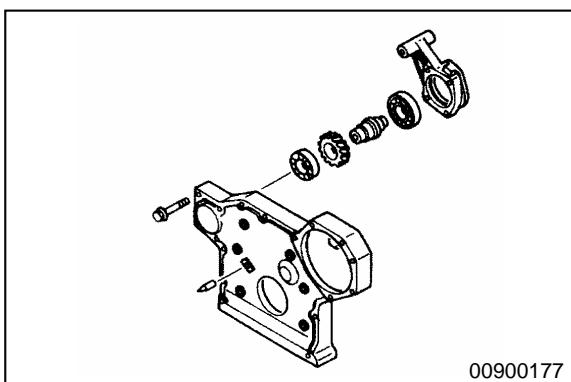
Install a new gasket, lubricating oil pan, and 24 capscrews.

Tighten the capscrews.

Torque Value: 32 N·m [24 ft-lb]

If the oil drain plug was removed, install the drain plug.

Torque Value: 51 N·m [38 ft-lb]



PTO Shaft (if applicable)

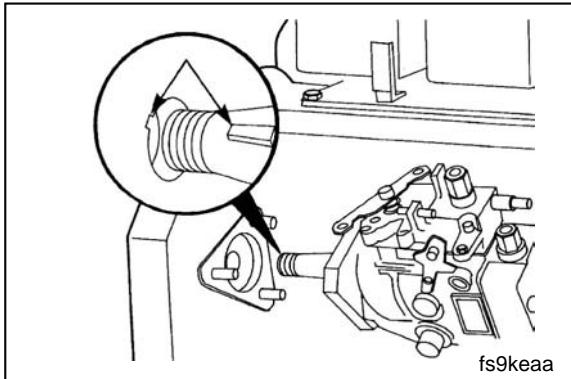


Align the gear of the PTO shaft with the surface teeth of the camshaft gear.

Install the o-ring, flange, and two capscrews.

Tighten the capscrews.

Torque Value: 19 N·m [14 ft-lb]



Fuel Injection Pump, Rotary



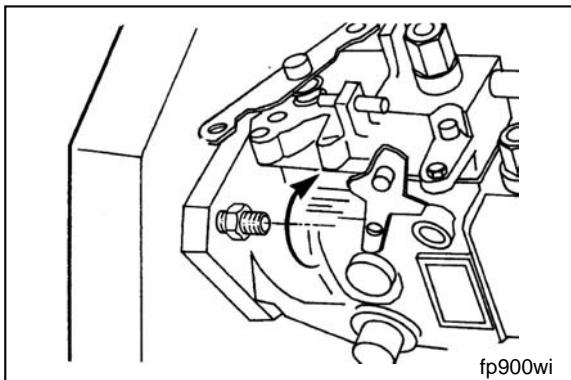
CAUTION

Make sure the key does not fall into the gear housing. Failure to do so can result in engine damage.

Install the Woodruff key into the fuel injection pump.

Align the key in the fuel injection pump with the keyway in the injection pump gear.

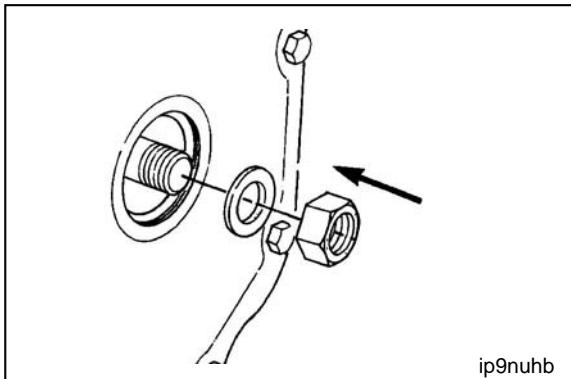
Install the fuel injection pump.



CAUTION

Do not attempt to pull the pump flange into the gear housing with the mounting nuts. Damage to fuel pump housing can occur.

Hand tighten the mounting nuts. The fuel pump must be free to move in the slots.



Install the fuel injection pump washer and nut.



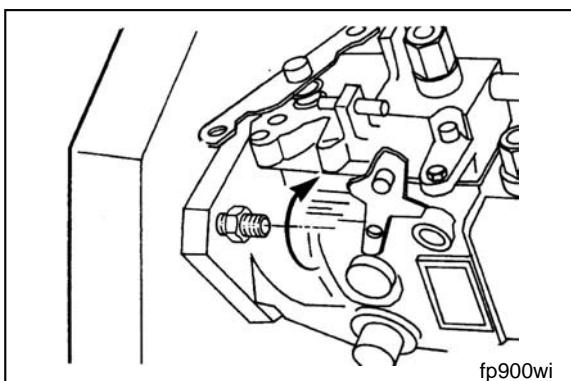
Tighten the nut.



Torque Value: 70 N·m [52 ft-lb]



Refer to the rotary fuel injection timing in this procedure to make sure the fuel pump is timed correctly.



Tighten the fuel injection pump mounting capscrews.



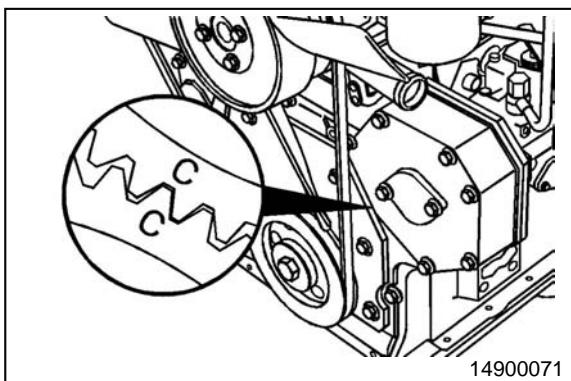
Torque Value: 31 N·m [23 ft-lb]



Install the mounting bracket capscrews.

Torque Value: 12 N·m [14 ft-lb]

Torque Value: 14 N·m [23 ft-lb]



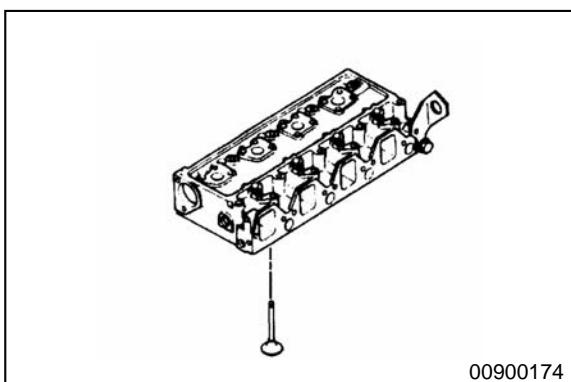
Install the fuel pump drive access cover.



Tighten the two capscrews.

Torque Value: 10mm 13 N·m [10 ft-lb]

Torque Value: 12mm 19 N·m [14 ft-lb]

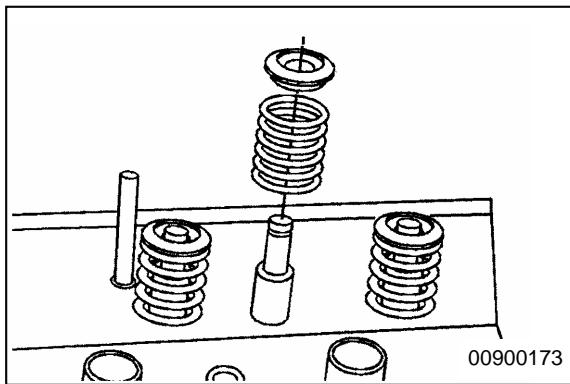


Cylinder Head Assembly

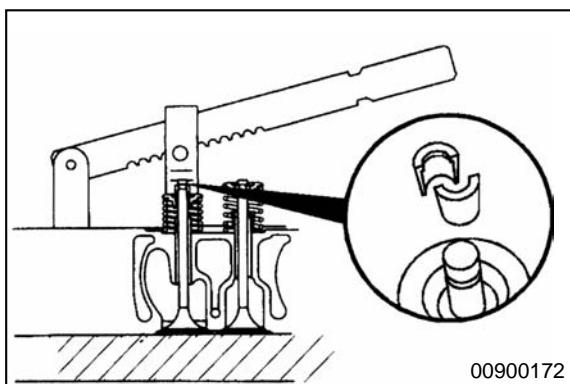


NOTE: Coat the stems of the intake and exhaust valves and the inside of the valve guides with engine oil.

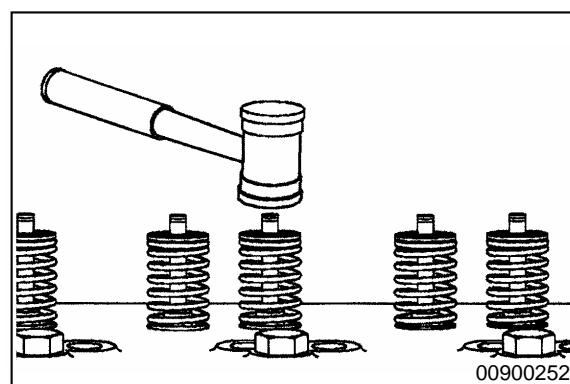
Install the valves.



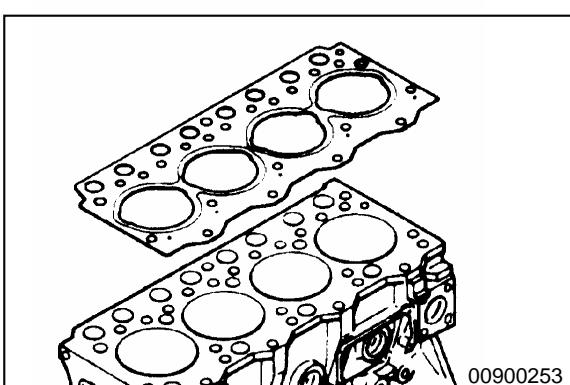
Install the valve spring and spring seat on the valve stem.



Install the valve cotter into the valve stem groove while compressing the valve spring with spring pusher, Part No. 3398179.



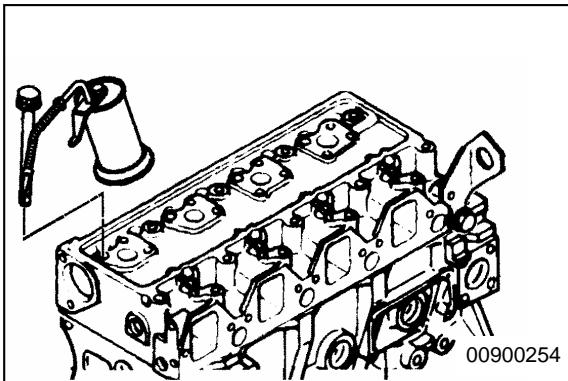
After releasing the valve spring, tap the top of the valve stem with a plastic hammer to make certain the cotter is completely fitted.



CAUTION

Remove all carbon and dirt from the contact surfaces of the cylinder block and the cylinder head. Remove all burrs and damage, and clean out all the dirt from inside the cylinder block. Failure to follow these steps will result in severe engine damage.

Install a new cylinder head gasket with the TOP mark facing up.



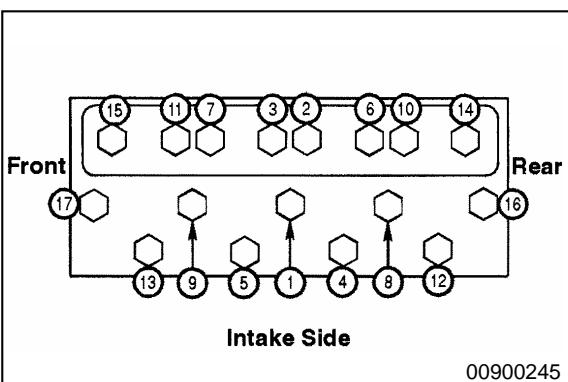
⚠ WARNING



This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

NOTE: Coat the capscrew threads with antifriction compound, Part No. 3824879.

Install the cylinder head using four head capscrews as guides.



Install the capscrews. Tighten the capscrews in the sequence shown.



Torque Value:

Cylinder Head

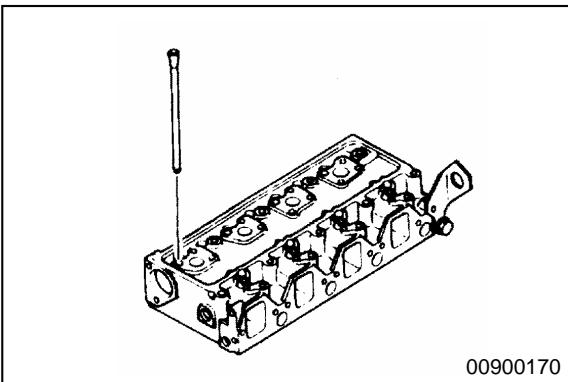
Capscrews

Step 1 69 N·m [51 ft-lb]

2 108 N·m [80 ft-lb]

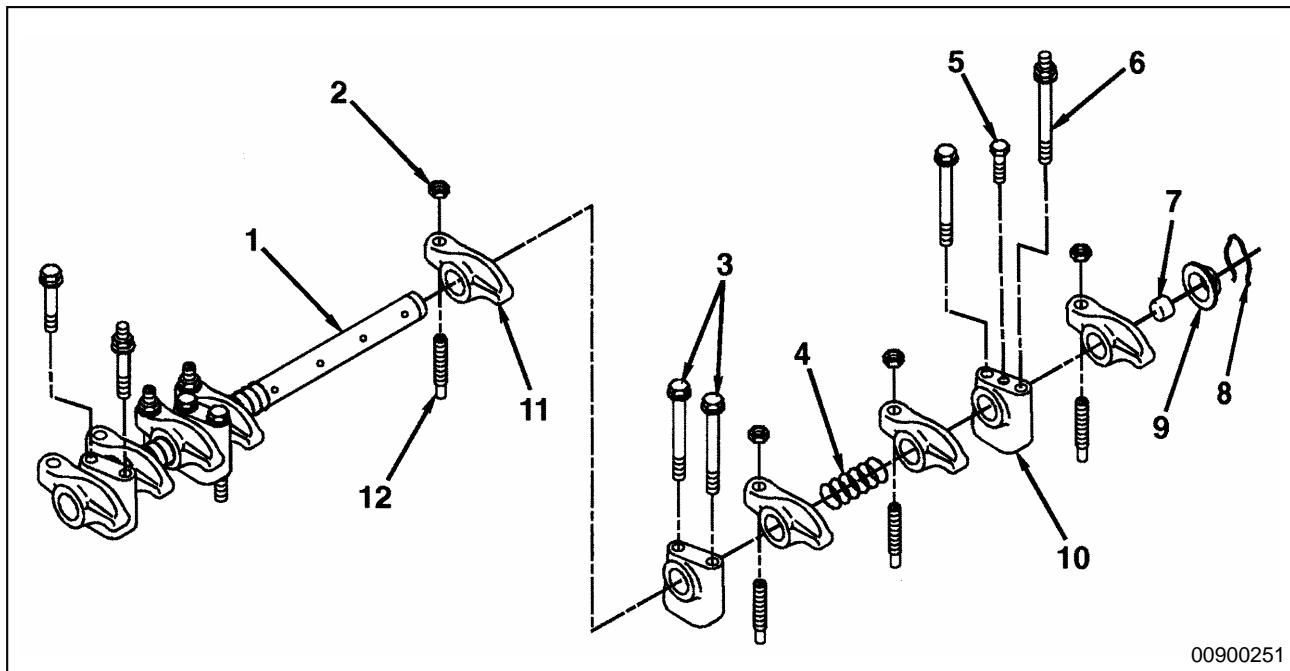
3 Rotate 90 degrees

NOTE: The cylinder head capscrews can be reused five times. Make a punch mark on the capscrew head each time the capscrew is used. If there are already five marks on the capscrew head, the capscrew **must** be replaced.



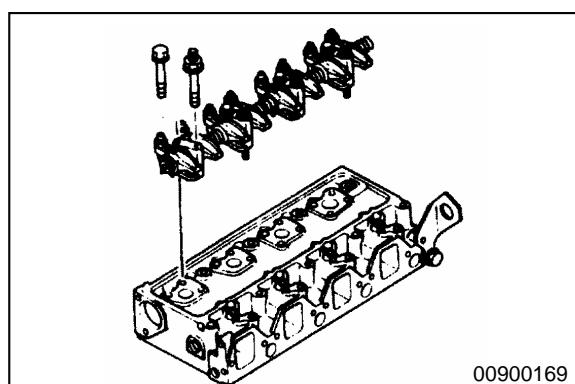
Push Rods

NOTE: If there is no abnormality in the pushrods, install them in the same position that they were removed from during disassembly.



Rocker Arm Assembly

1. Rocker Shaft	7. Cup Plug
2. Adjusting Screw Lock Nut	8. Snap Ring
3. Pedestal Mounting Capscrews	9. Thrust Washer (only used on some engines)
4. Separating Spring	10. Rocker Lever Pedestal
5. Rocker Shaft Indexing Screw	11. Rocker Lever
6. Pedestal Mounting Stud	12. Adjusting Screw.

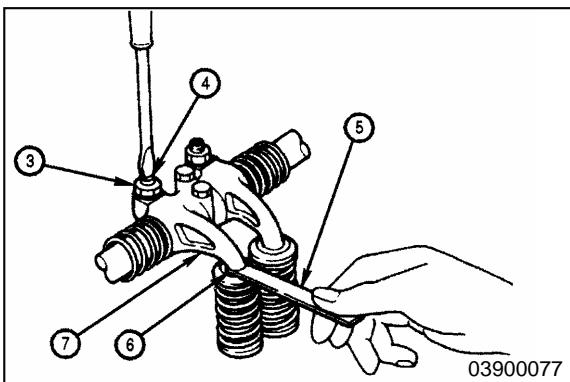


Rocker Arm Assembly

NOTE: Check that the ball of the adjustment screw is fitted properly into the socket of the pushrod before tightening the capscrews. If the valve spring tension pushes against the rocker arm, loosen the locknut, and turn the adjustment screw back to prevent strain on the pushrod.

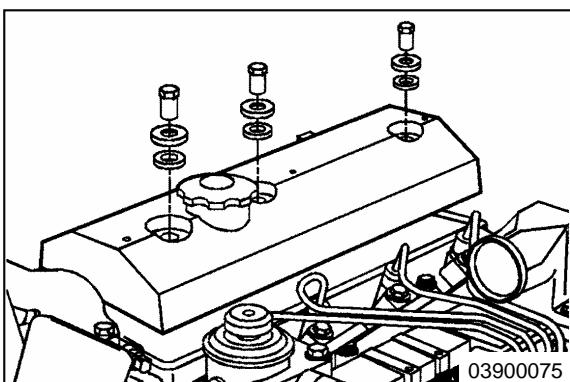
Install the rocker arm assembly and eight capscrews. Tighten the capscrews.

Torque Value: 25 N·m [18 ft-lb]



Adjusting Valve Clearance

Adjust the valve clearance. Refer to Section 14.



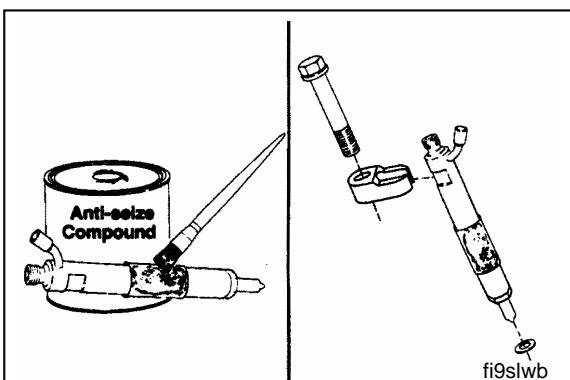
Rocker Lever Cover

Install the o-ring into the rocker lever cover.

Install the rocker lever cover, three capscrews, and isolator assemblies.

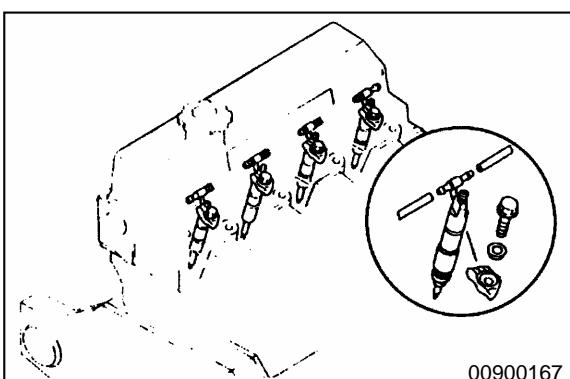
Tighten the capscrews.

Torque Value: 9 N·m [7 ft-lb]



Injector

Coat the injectors with anti-sieze compound, Part No. 3824879, before installation.



CAUTION

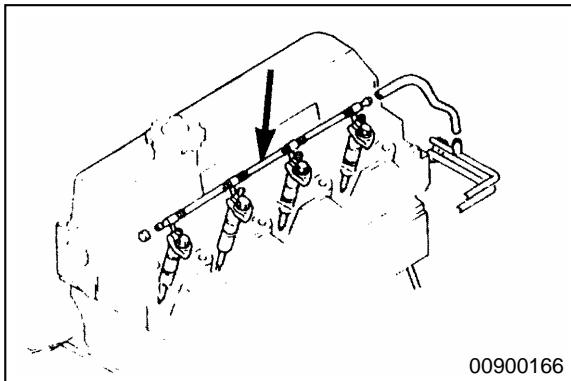
Be careful not to damage the tip of the injector when installing.

NOTE: When installing the injector, clean around the injector, and do **not** allow dust or dirt to enter the engine.

NOTE: If there is no abnormality in the injector, install it in the same position during assembly.

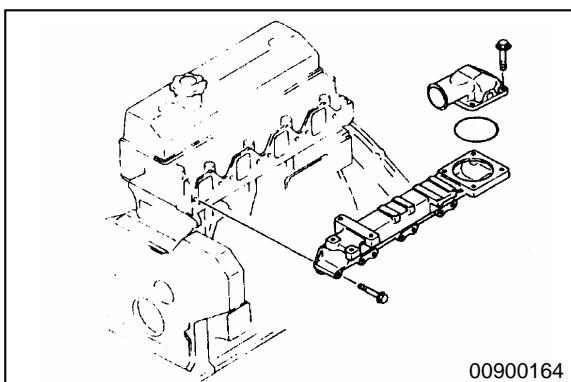
Install the injector, washer, and mounting capscrew. Tighten the capscrew.

Torque Value: 44 N·m [33 ft-lb]



Spill Tube

Install the spill tube.



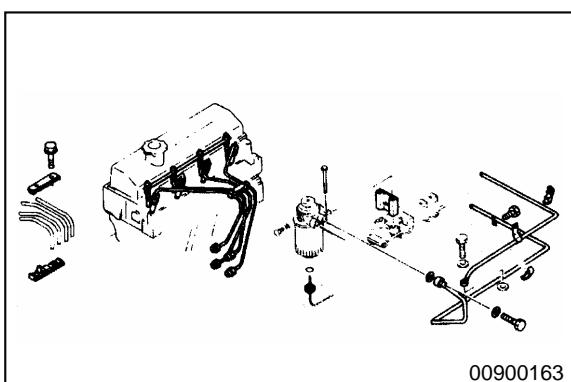
Intake Manifold

NOTE: Apply a 1-mm [0.039-in] bead of gasket sealant, Part No. 3823494, to the mounting surface of the intake manifold.

Install the air inlet connection, intake manifold, and seven capscrews.

Tighten the capscrews.

Torque Value: 40 N•m [30 ft-lb]



Fuel Injection Tubing

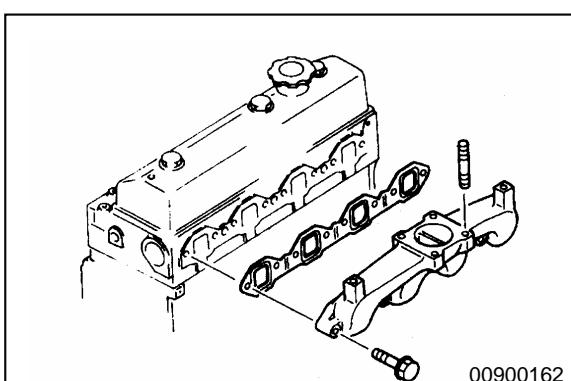
NOTE: Before installing the fuel injection tubing, blow compressed air through it to clean it.

Position the fuel injection tubing, and loosely install the sleeve nuts on the fuel injection pump and the cylinder head.

Tighten the clamp.

Tighten the banjo fittings

Torque Value: 20 N•m [15 ft-lb]



Exhaust Manifold

Install a new gasket, the exhaust manifold, and the eight capscrews.

Tighten the capscrews.

Torque Value: 66 N•m [49 ft-lb]



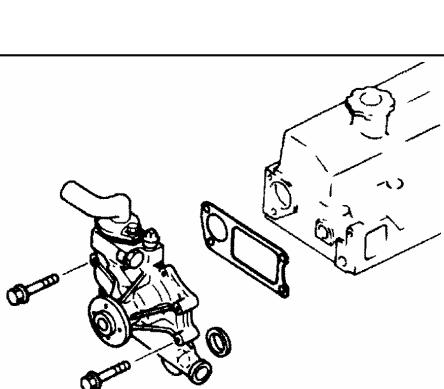
18900025

Thermostat



Install seal, thermostat, thermostat housing, and two mounting capscrews.
Tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



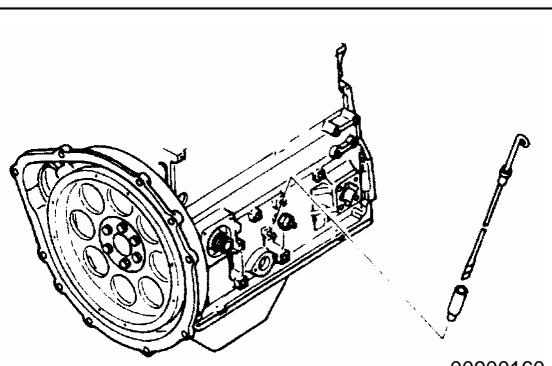
00900161

Water Pump



Install the o-ring, gasket, water pump, and mounting capscrews.
Tighten the capscrews.

Torque Value: 19 N•m [14 ft-lb]



00900160

Dipstick



NOTE: Apply Loctite™ sealant, Part No. 3375068, or equivalent, to the outside of the dipstick tube.

CAUTION

Excessive sealant can run back into the engine and cause damage to other components.

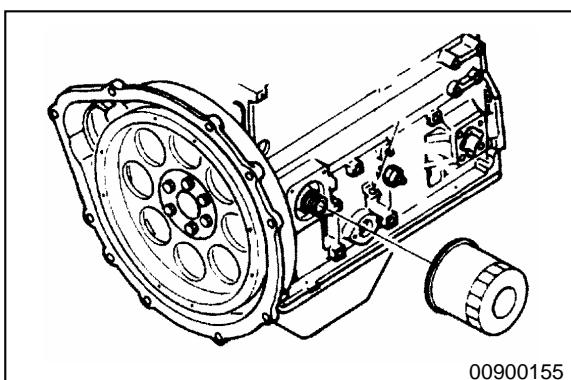
Install the dipstick guide.
Install the dipstick.



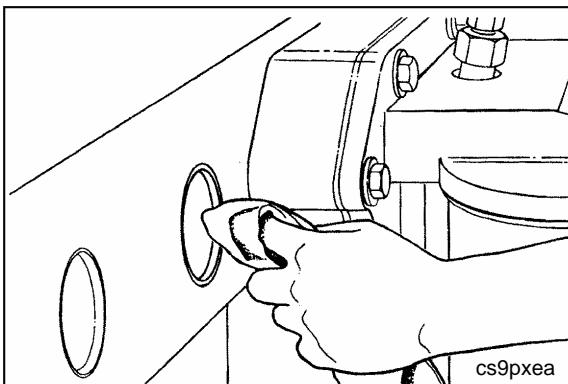
Lubricating Oil Filter

Install the lubricating oil filter.

NOTE: Some engines will have an oil filter cooler mounted between the oil filter and the engine block.



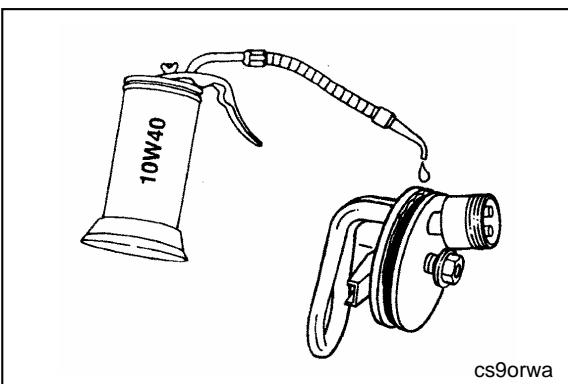
00900155



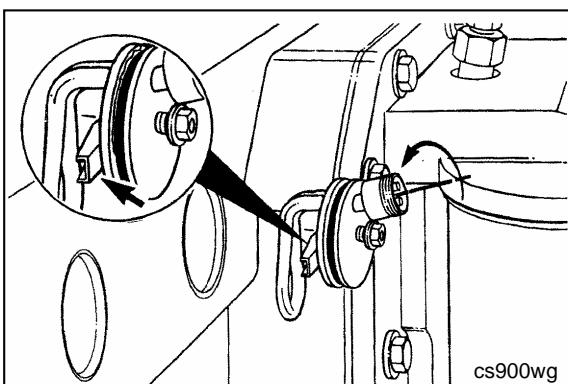
Block Water Heater



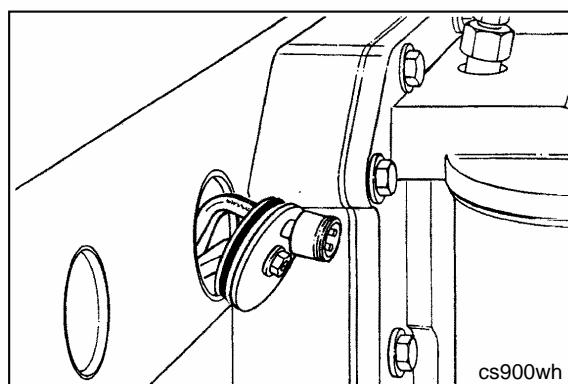
Clean the core plug hole thoroughly. Make sure there are **not** burrs or sharp edges that might cut the o-ring.



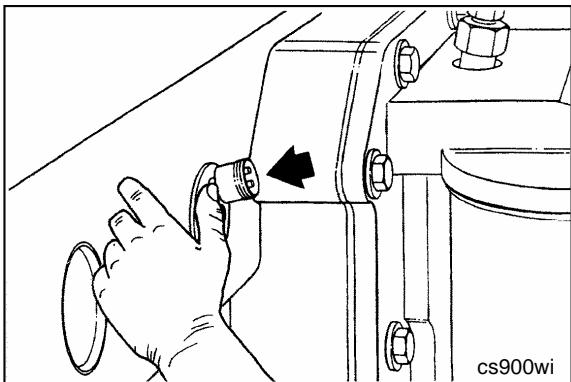
Lubricate the new heater o-ring with clean engine oil.



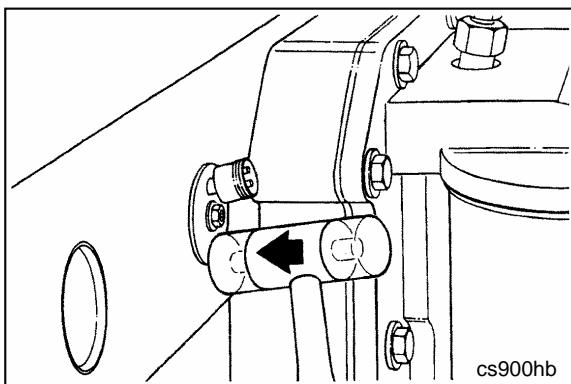
The locking channel (T-Bar) should be threaded out to the end of the bolt. If so equipped, do **not** remove the retaining wire used to position the channel (T-Bar).



Hook the element and one leg of the channel (T-Bar) into the hole as illustrated.



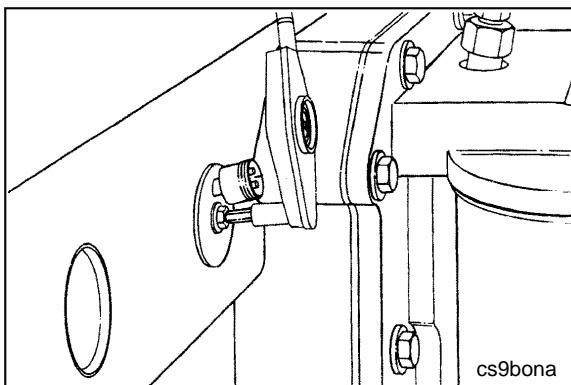
Hook the other leg of the channel in the hole and push the heater into the hole as far as possible by hand.



⚠ CAUTION

Do not pull the heater into location with the locking bolt as the channel (T-Bar) can bend or cause the threads to strip.

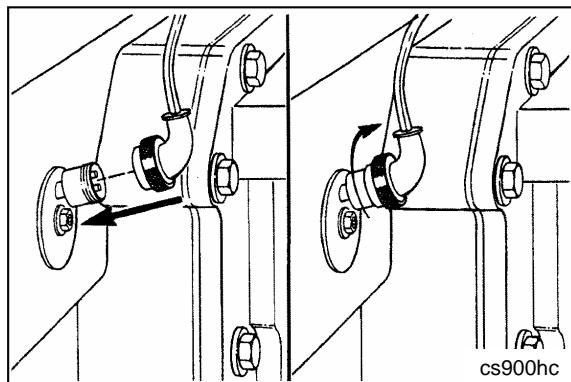
If necessary, use a plastic hammer to tap the heater in until the shoulder contacts the block.



Tighten the locking bolt.

Torque Value: 2.0 N•m [18 in-lb]

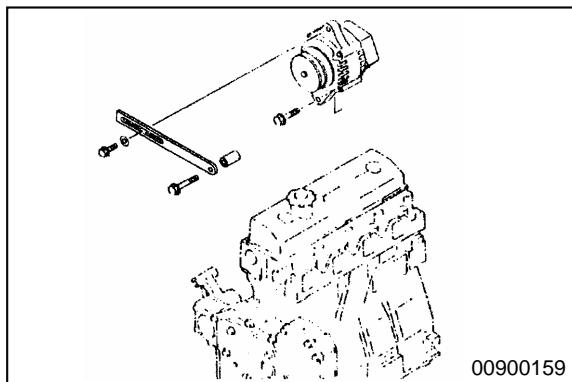
Do **not** over-tighten the locking bolt.



Insert the power cord into the socket being careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.

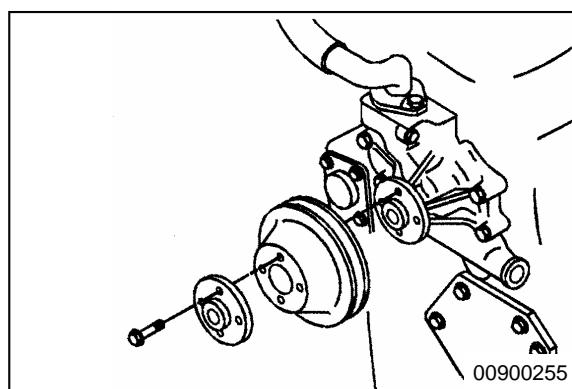
Do **not** apply power until the cooling system is filled, and run the engine long enough for the thermostats to open and ensure all the air has escaped.





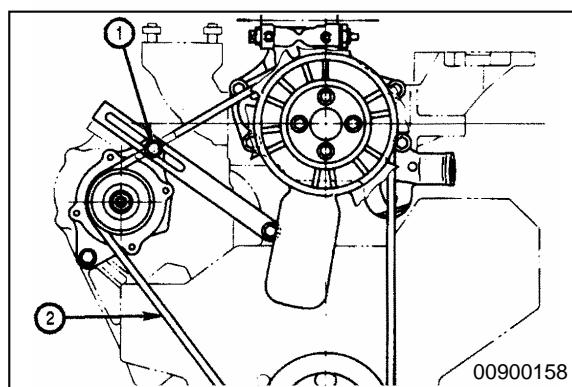
Alternator

Install the alternator and capscrew.
Install the spacer, mounting capscrew, and adjustment plate.
Loosely install the washer and adjustment capscrew.

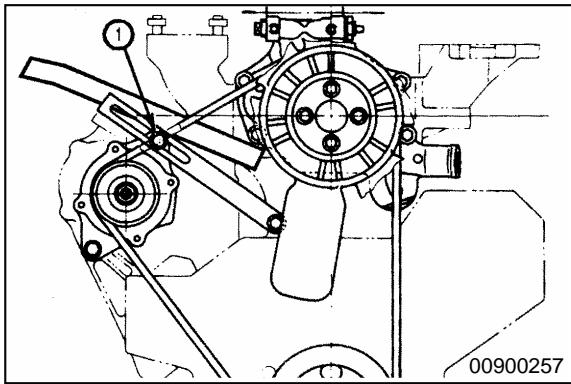


Fan Pulley

Install the fan pulley.



Position the fan belt (2) into the fan pulley groove, and loosely tighten the adjustment capscrew (1).



⚠️ WARNING

Be careful not to injure your fingers or damage the alternator when adjusting the belt tension.

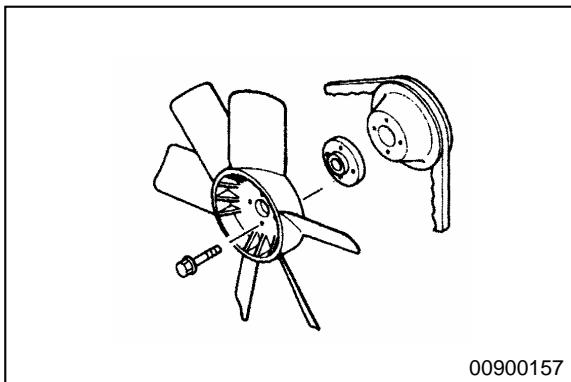
Insert a bar or pipe between the alternator and the cylinder block. Raise the alternator to adjust the fan tension.

NOTE: The belt **must** deflect 7 mm to 10 mm [0.28 in to 0.39 in] when pushed with finger-pressure of 6 kg [13 lb] at a point midway between the fan pulley and the crankshaft pulley.

Tighten the adjustment capscrew (1).

Torque Value:

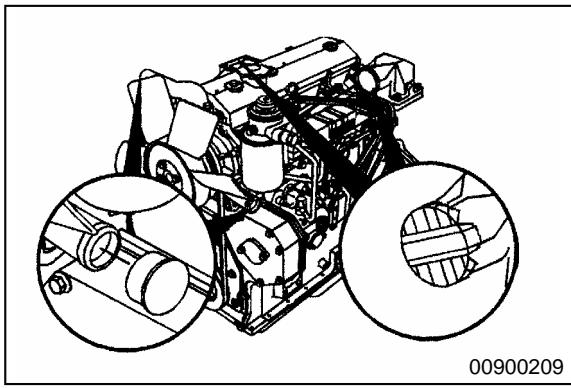
Mounting Capscrew	31 N•m	[23 ft-lb]
Adjustment Capscrew	31 N•m	[23 ft-lb]



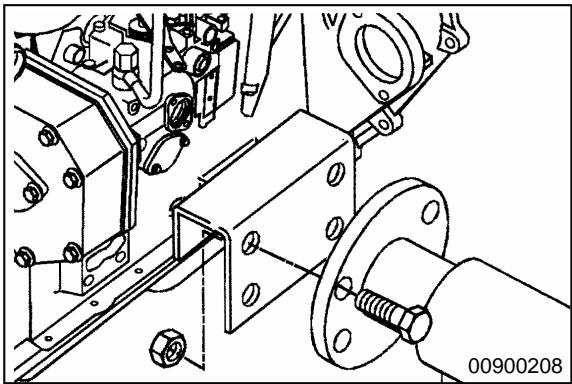
Fan

Install the spacer, fan, four capscrews. Tighten the capscrews.

Torque Value: 31 N•m [23 ft-lb]



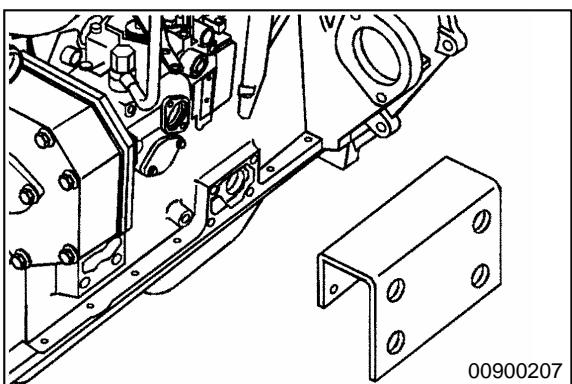
Remove the covers on all the engine openings that were installed to prevent dirt and debris from entering the engine.



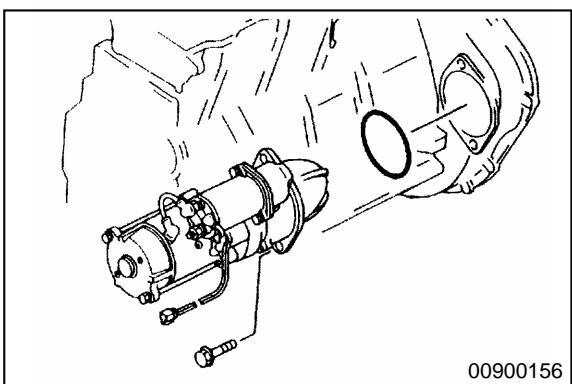
⚠️ WARNING

This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component. The engine lifting equipment must be designed to lift the engine without causing personal injury.

Engine Weight (approx.) 330 kg [660 lb]
Remove the engine from the stand.



Remove the bracket, Part No. 3163625, from the engine.

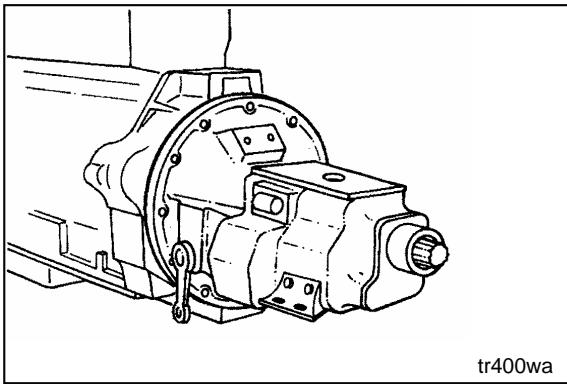


Install the starting motor.

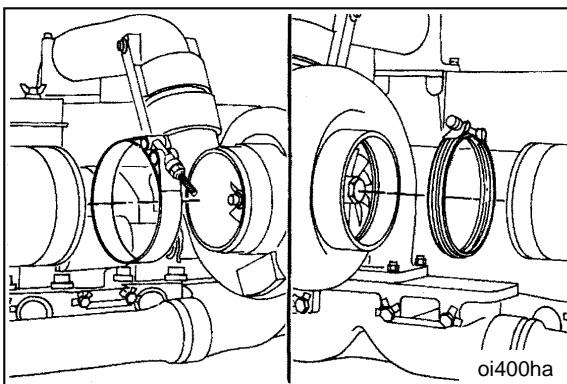
NOTE: The o-ring is used **only** on wet flywheel housings.



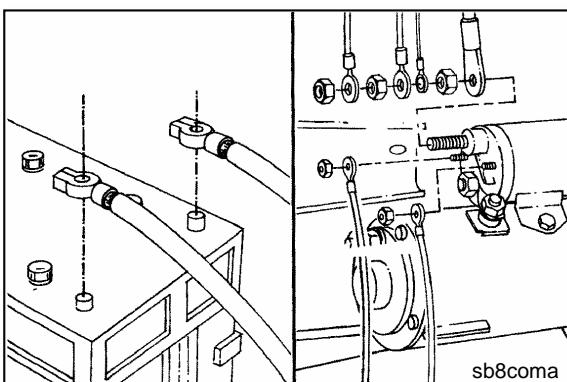
Install all the chassis components that were removed during removal of the engine from the equipment.



Connect the drive units to the flywheel housing and flywheel.



Connect the intake and exhaust system pipes.

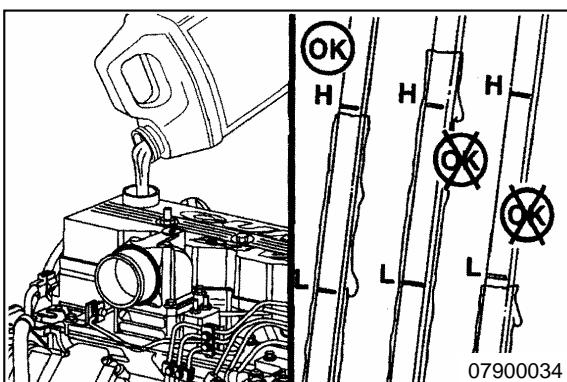


Connect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, and hydraulic lines.

WARNING

Always connect the negative (-) cable last.

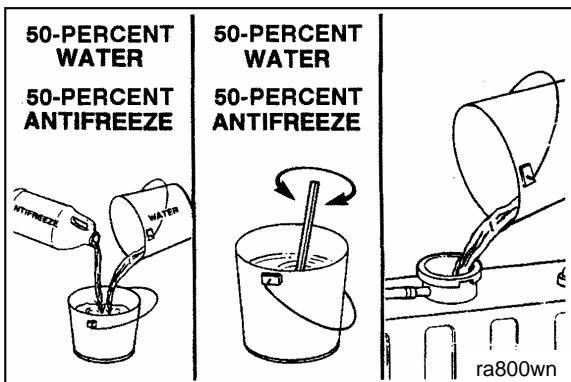
Connect the battery cables.



WARNING

Some state and federal agencies in the United States of America have determined that used oil is carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. Always use the proper procedures to dispose of the oil.

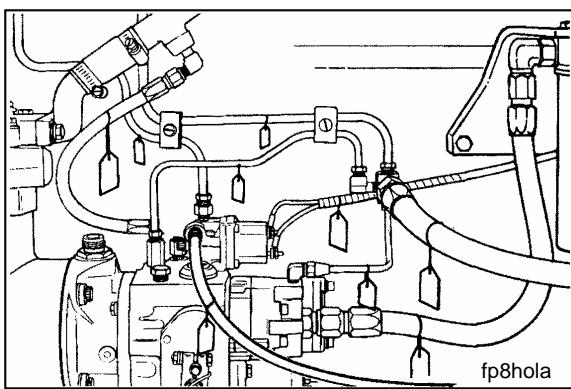
Fill the engine with lubricating oil.
Engine Oil 6.5 liters [1.7 u.s.gal]



⚠️ WARNING

Coolant is toxic. Keep away from children and animals. Save for reuse or dispose of in accordance with local regulations.

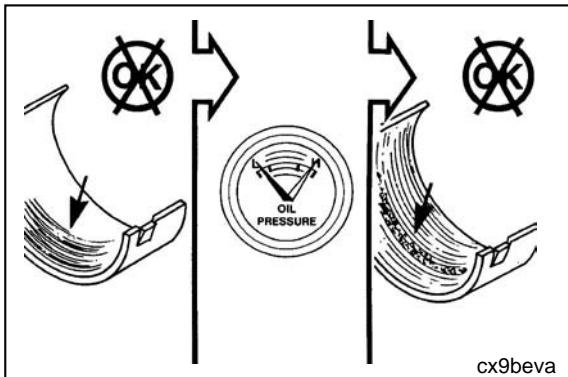
Fill the engine with engine coolant.



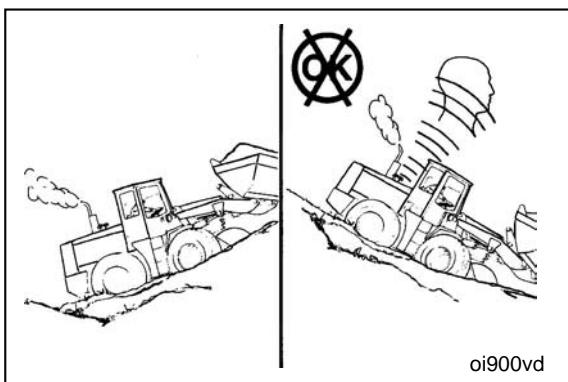
NOTE: Remove all tags that were put on all hoses, lines, linkage, and electrical connections as they were removed to identify location during the removal process.

Engine System

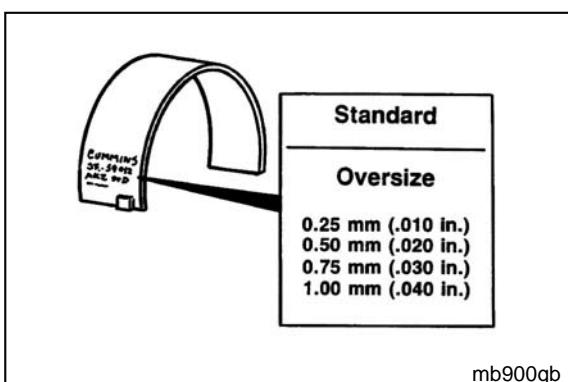
Bearing, Connecting Rod



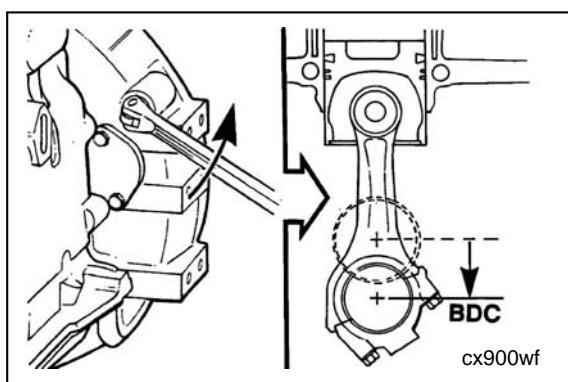
Normally, worn bearings can be detected by reduced oil pressure, but if this wear goes undetected, the excessive clearance will increase the impact between the bearing and crankshaft, causing a distinct knocking sound.



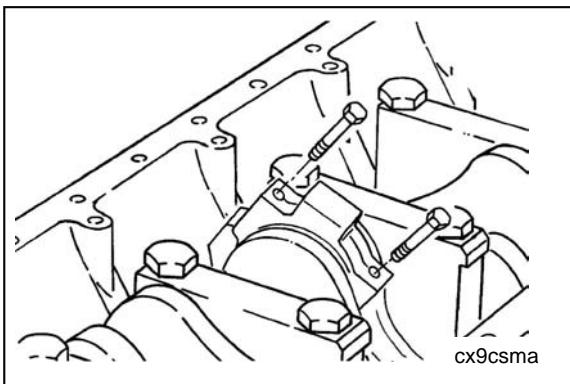
A connecting rod noise occurs when the engine is not loaded. Check by first applying a load, and then unloading and listening for the noise.



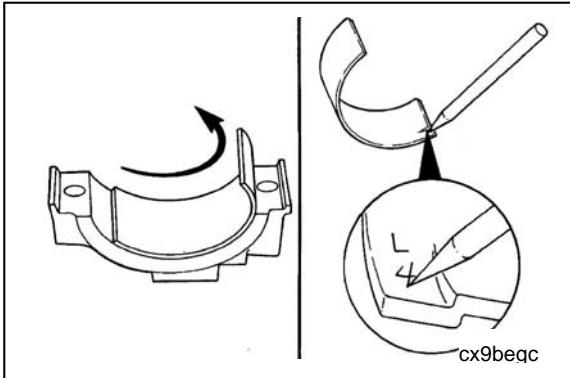
The connecting rod bearing shells are identified by steel-stamped characters on the back of the bearings. The characters indicate either standard (STD) or the amount of oversize (OS).



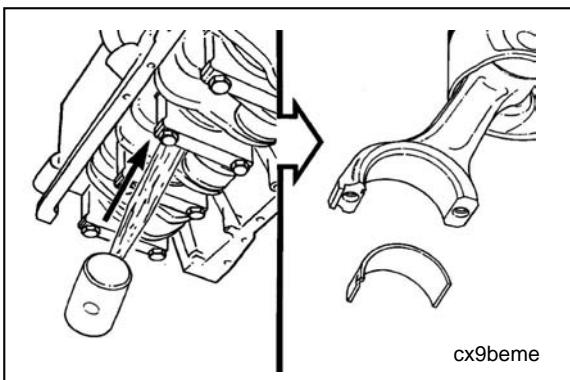
Use a barring tool to rotate the crankshaft to the bottom dead center (BDC) position of the connecting rod.



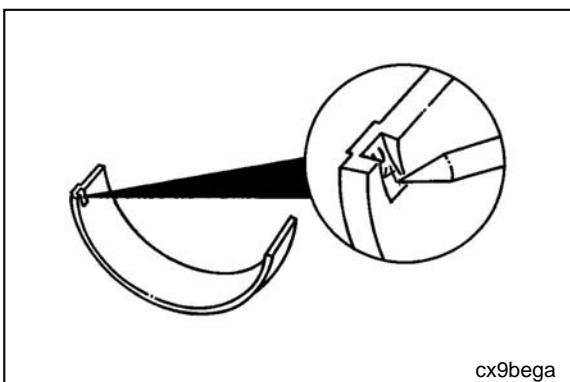
Remove the connecting rod capscrews and connecting rod caps.



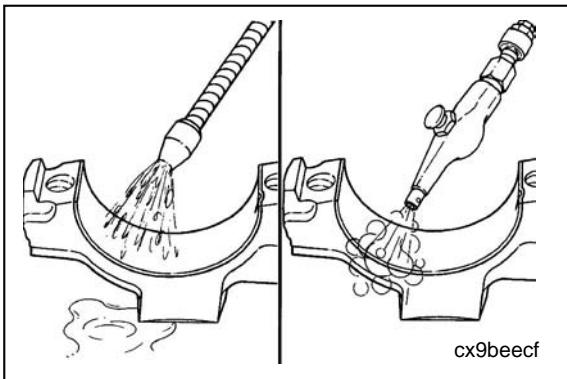
Remove the lower bearing shell from the connecting rod cap, and mark it with the letter L (lower) and the cylinder number from which it was removed.



Push the connecting rod away from the crankshaft to allow the upper bearing shell to be removed.



Remove the upper bearing shell, and mark it with the letter U (upper) and the cylinder number from which it was removed.



⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ WARNING

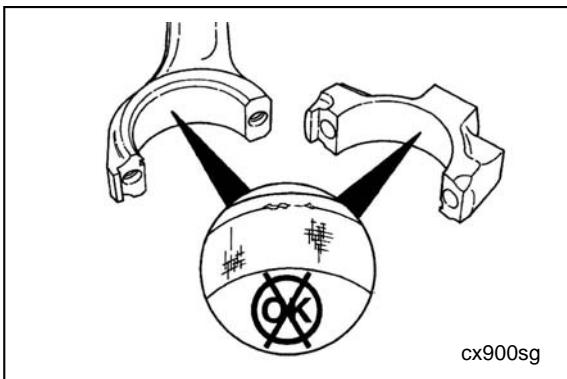
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠️ WARNING

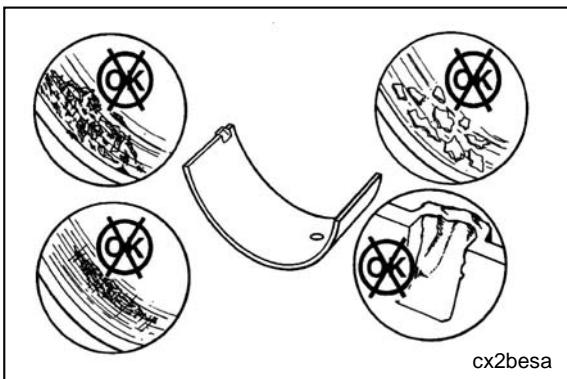
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the bearing and connecting rod caps with solvent.

Dry with compressed air.



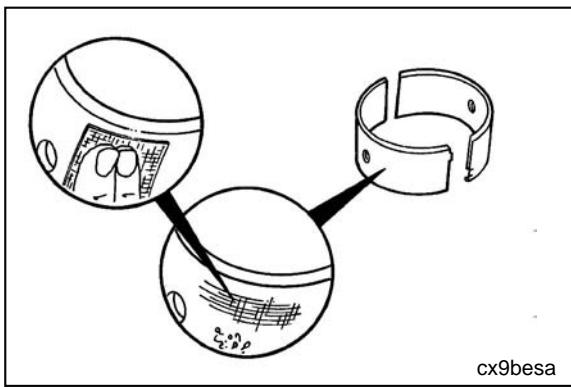
Inspect the connecting rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage. Refer to Parts Reuse Guidelines, for more information on bearing inspection.

Replace any bearings that have the following damage:

- Pits
- Flakes
- Corrosion
- Lock tang damage
- Scratches
- Heavy wear.

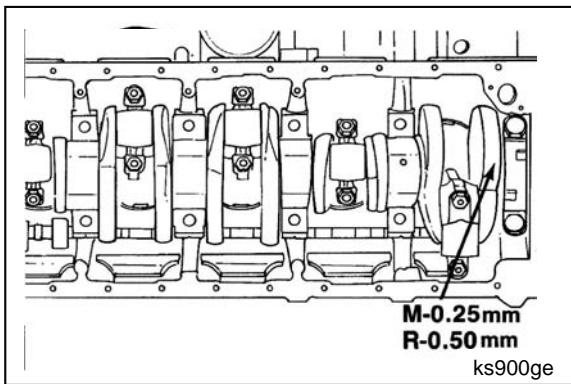


Inspect the bearing shell seating surface for nicks or burrs.



If nicks or burrs can not be removed with an abrasive pad, Part Number 3823258, or equivalent, the bearings must be replaced.

If the bearings are damaged, they must be replaced as a set. For more detailed information on bearing damage, see Analysis and Prevention of Bearing Failures.

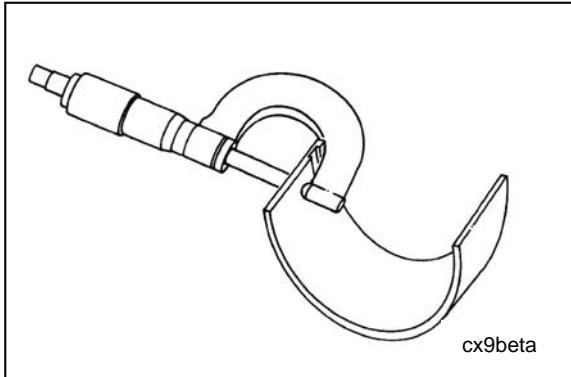


NOTE: Connecting rod bearings are identified with the part number and size stamped on the back.



NOTE: Oversize service rod bearings are available for use with a crankshaft that has been machined undersize.

Determine the size of the removed rod bearing, and obtain a set of the same size.



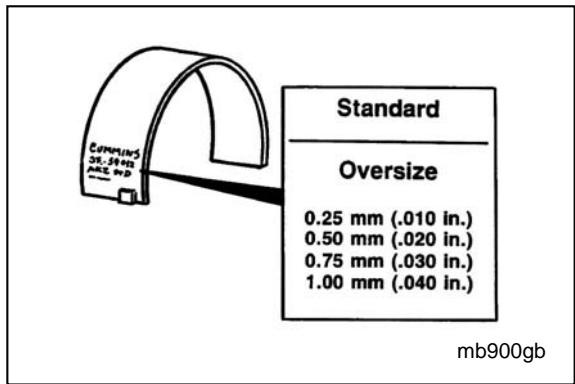
Use an outside diameter ball-tipped micrometer to measure the connecting rod bearing thickness.

B3.3 Connecting Rod Bearing Thickness

	mm	in
Standard	3.80	MIN 0.1496
	4.00	MAX 0.1575

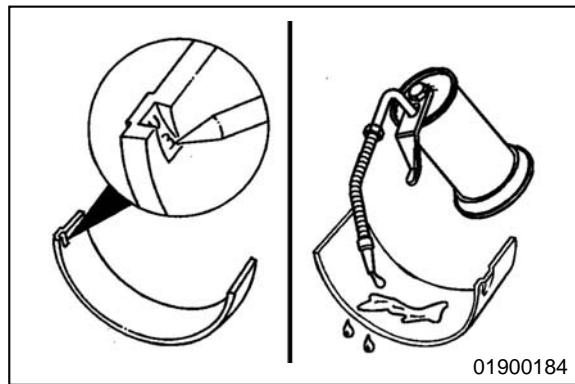
B3.3 Connecting Rod Bearing Thickness for Oversize Bearings

	mm	in
0.25mm	4.05	MIN 0.1594
	4.25	MAX 0.1673
0.50mm	4.30	MIN 0.1693
	4.50	MAX 0.1772
0.75mm	4.55	MIN 0.1772
	4.75	MAX 0.1870
1.00mm	4.80	MIN 0.1890
	5.00	MAX 0.1968



 **NOTE:** Bearing shells are identified by steel-stamped characters on the back of the bearings to indicate either standard (STD) or oversize (OS).

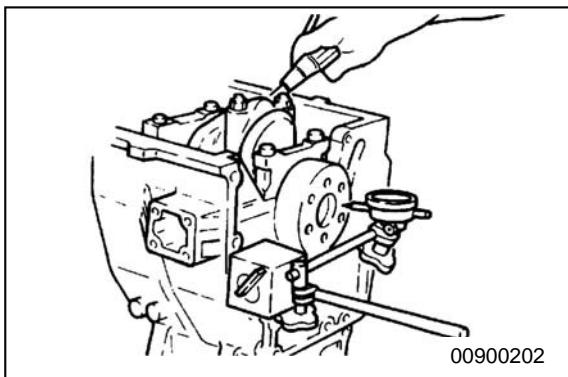
A crankshaft that is machined undersize on the connecting rod or main bearing journals is marked on the front counterweight. If the crankshaft is marked, check the bearing shell part number to make sure the correct bearing size is used.



 **NOTE:** Used bearings must be installed in the same location from which they were removed.

Refer to Procedure 001-054 for connecting rod bearing installation instructions.

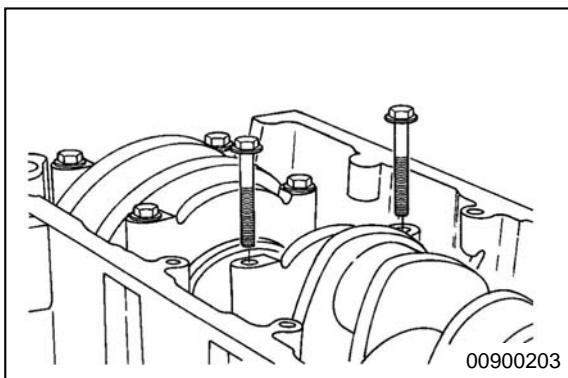
Bearing, Main



NOTE: The end play measurement is necessary for determining the wear of the thrust bearing and abnormal wear of the crankshaft.

Measure the crankshaft end play using a dial indicator, Part Number 3824564, or equivalent, and magnetic base, Part Number 3377399, or equivalent.

Crankshaft End Play		
Mm	in	
0.131	MIN	0.0052
0.351	MAX	0.0138

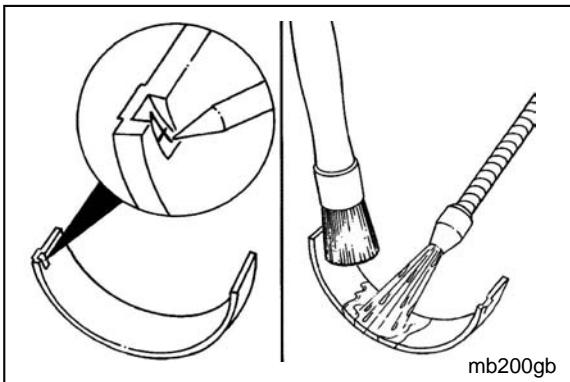


NOTE: Mark the thrust bearings so the bearings can be installed in the correct position during assembly.

NOTE: The main bearing cap mounting capscrews must be replaced after each use.

Remove the mounting capscrews of the main bearing cap.

Remove the main bearing cap and lower bearing.



⚠ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

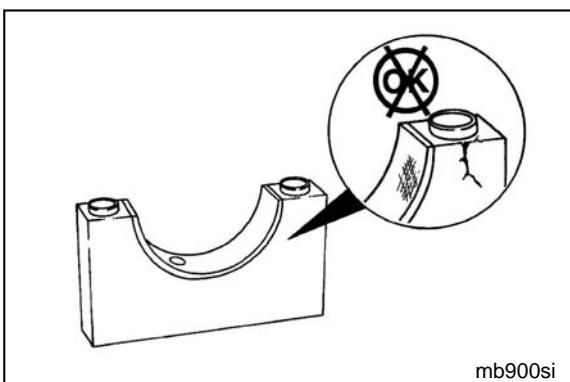
⚠ CAUTION

Do not use a scraper or a wire brush. The bearings can be damaged.

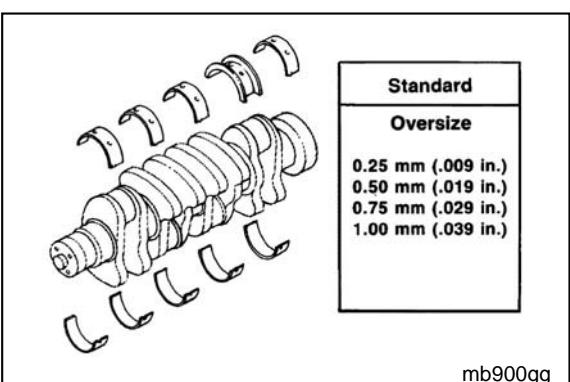
NOTE: Make sure the bearings are marked for location. The bearings must be installed in their original locations, if used again.

Use solvent and a soft bristle brush to clean bearings.

Dry with compressed air.



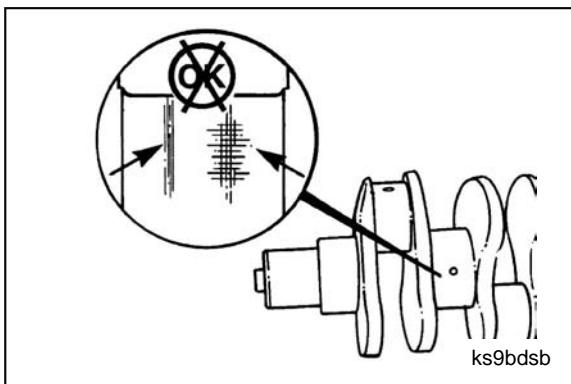
Inspect all main bearing caps and main bearing crankshaft journals for dents, cracks, deep scoring, overheating, and other damage.



Determine the size of the main bearing removed and obtain the same size for installation.

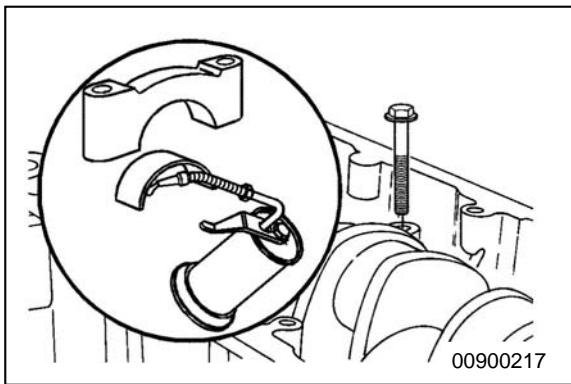


Refer to Part Reuse Guidelines for the dimensions of the standard and undersize main bearing journals.



NOTE: If the crankshaft journals or main caps are damaged, the engine will need to be removed to complete the overhaul.

Inspect the crankshaft journals for deep scratches, indications of overheating, and other damage.



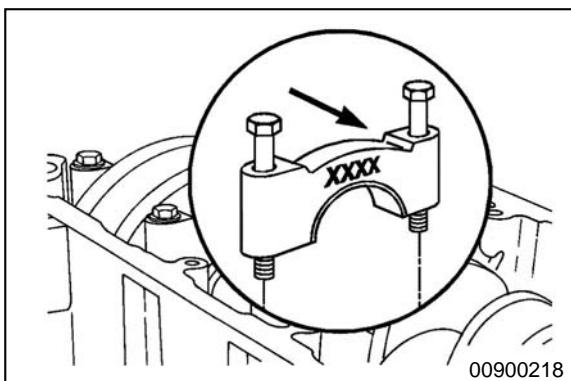
⚠ CAUTION

Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Remove debris behind the bearing before installation.

Coat the inside face of the bearing with clean SAE30 engine lubricating oil before installation. The number stamped on the main bearing cap must be the same as the number stamped on the cylinder block.

Align the protrusion in the lower main bearing with the notch in the cap.

Install the lower main bearing into the main bearing cap.

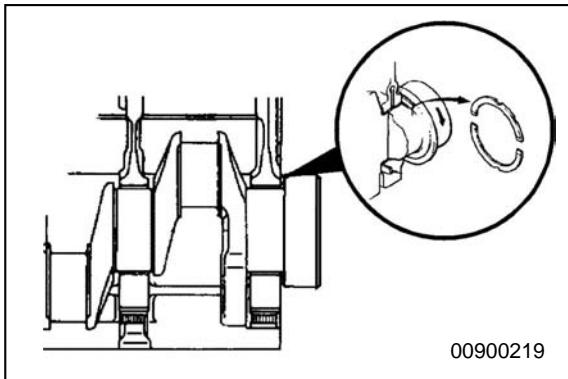


NOTE: New main bearing mounting capscrews must be used.

The casting number or cast arrow on the main bearing cap must face toward the front of the engine.

Coat the capscrew threads and seat face with clean SAE30 engine lubricating oil.

Position the main bearing caps and capscrews.



00900219

⚠ CAUTION



Install each thrust bearing with the oil groove on the outside. Failure to do so will cause engine damage.

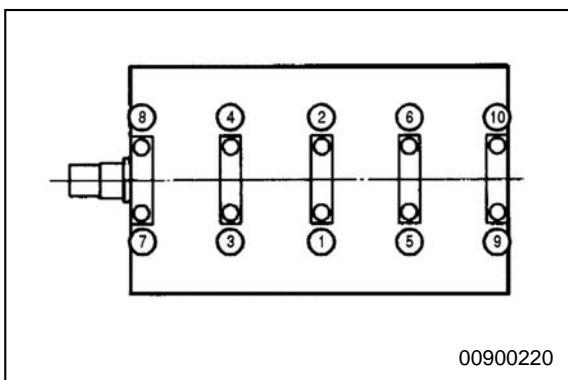
⚠ WARNING



Do not let the thrust bearings slip out of place. Engine damage will result if the thrust bearings are not properly installed.

The casting number or cast arrow on the main bearing cap must face toward the front of the engine. The thrust bearing is located on the main bearing closest to the rear of the engine (number 5). Align the lower thrust bearing with the dowel pin.

Install the upper thrust bearing.



00900220

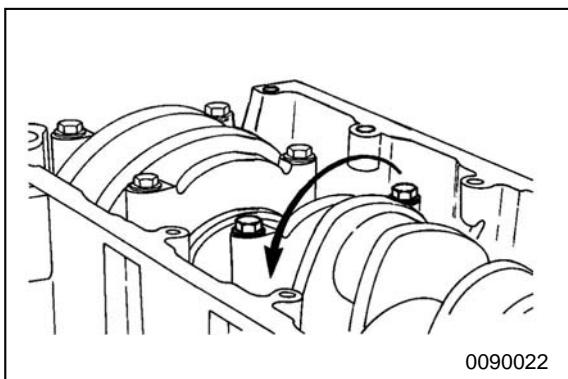


Tighten the mounting capscrews in the order shown in the illustration.



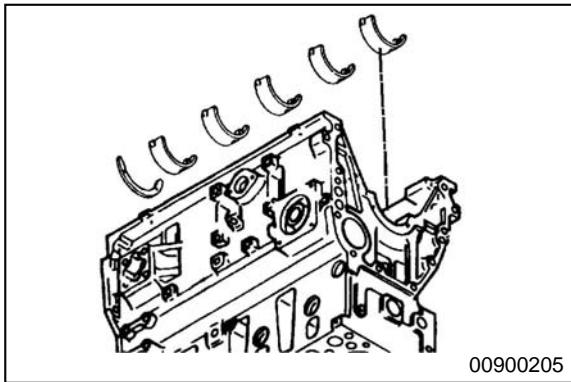
Torque Value:

- Step 1 113 N·m [83 ft-lb]
- Step 2 Loosen all capscrews completely.
- Step 3 132 N·m [98 ft-lb]



0090022

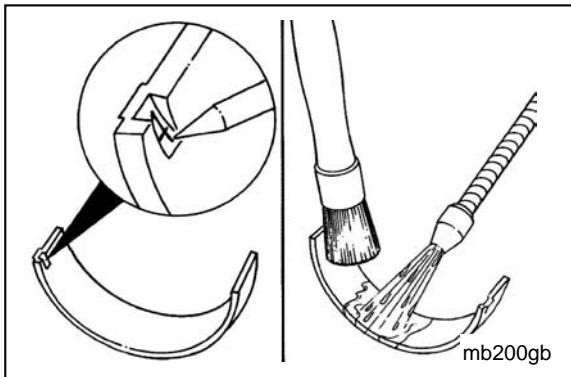
After the mounting capscrews are tightened, make sure the crankshaft rotates smoothly.



NOTE: Mark the lower main bearings and the two lower thrust bearings so that they can be installed in the correct position.

Remove the upper thrust bearing.

Bearing, Thrust



WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.



Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

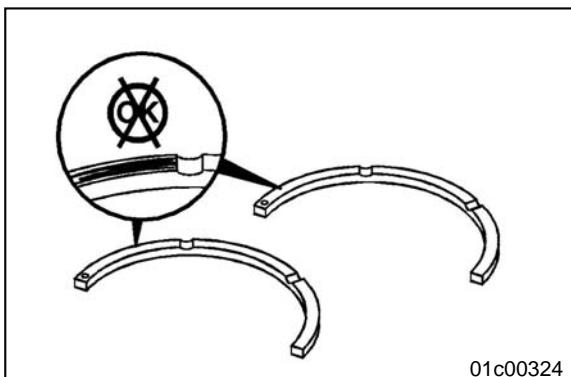


Do not use a scraper or a wire brush. The bearings can be damaged.

NOTE: Make sure the bearings are marked for location. The bearings must be installed in their original locations, if used again.

Use solvent and a soft bristle brush to clean bearings.

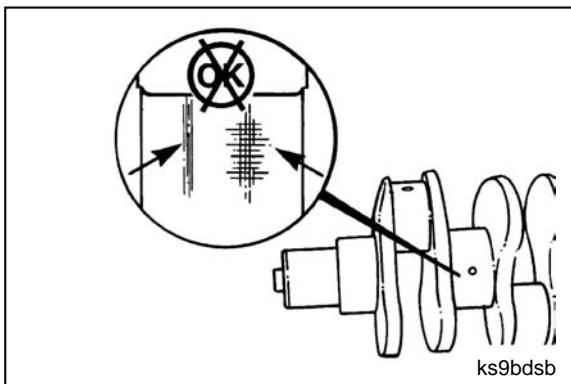
Dry with compressed air.



NOTE: If damage is found on any of the thrust bearings, make sure to inspect the crankshaft, block, and main bearing caps for damage as well.

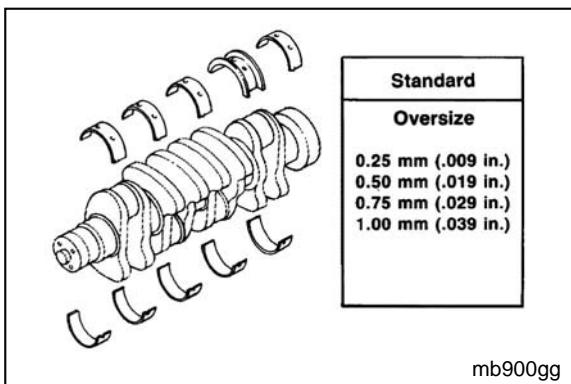
Inspect the thrust bearings for scratches, galling, uneven wear, or other damage.

Replace the thrust bearings, if damage is found.



Inspect the crankshaft journals for deep scratches, indications of overheating, and other damage.

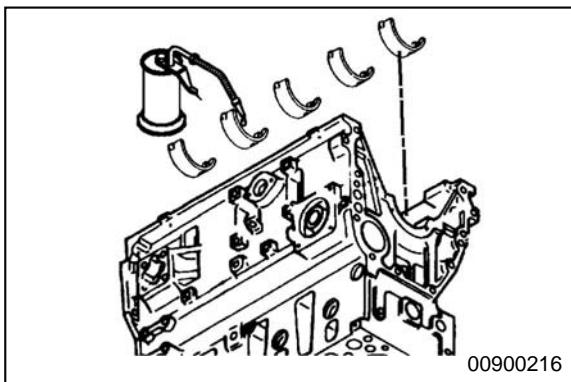
Replace the crankshaft if excessive damage is found.



Determine the size of the thrust bearings removed, and obtain the same size for installation.



Refer to Part Reuse Guidelines for the dimensions of the standard and undersize main bearing journals.



CAUTION



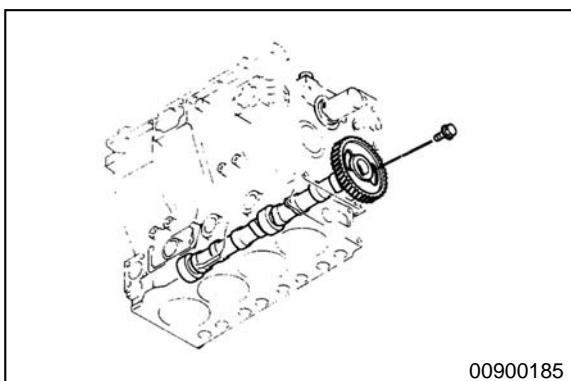
Confirm that there is no dirt or dust stuck to the rear face of the bearing before installation. Debris behind the bearing can cause severe engine damage.

Coat the inside face of the bearing with clean SAE30 engine lubricating oil before installation.

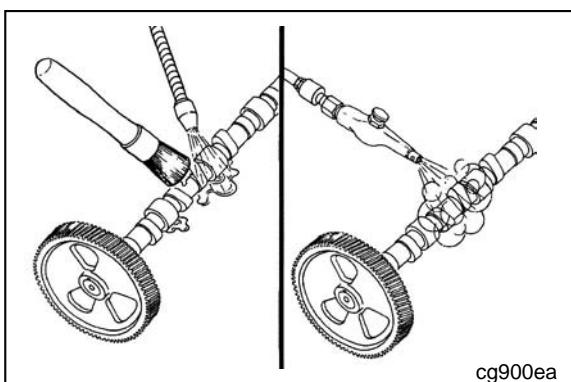
Align the protrusion in the thrust bearing with the notch in the cylinder block.

Install the upper thrust bearing into the cylinder block.

Camshaft



Remove the two mounting capscrews through the casting holes in the camshaft gear.



⚠ WARNING

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING

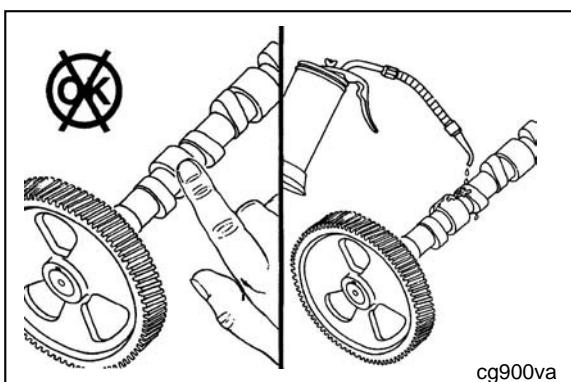
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use solvent or steam to clean the camshaft.

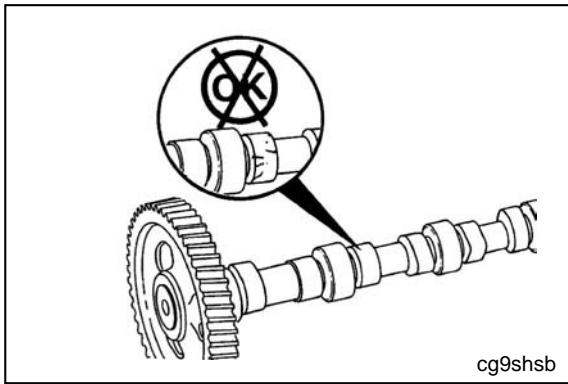
Dry with compressed air.



⚠ CAUTION

Do not touch the machined surfaces with bare hands; this can cause rust to form on the camshaft.

Before the camshaft is touched, lubricate the camshaft with clean engine lubricating oil.

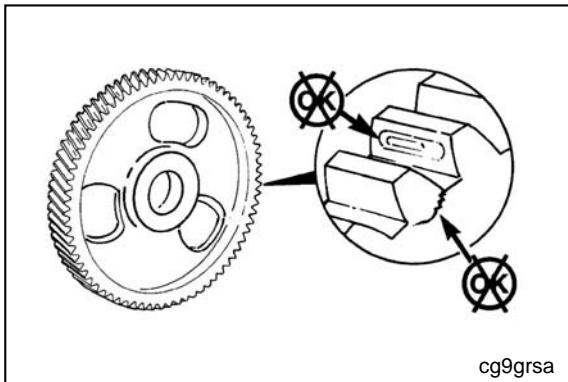


NOTE: When a new camshaft is installed; new tappets and push tubes must be installed also.



Inspect the bearing journals for cracking, pitting, or scoring.

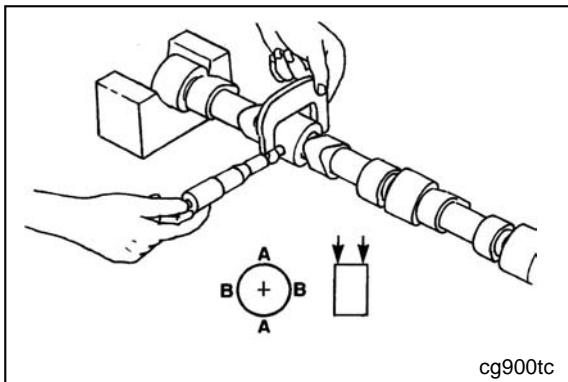
Contact a Cummins Authorized Repair Location for pitting reuse criteria.



Inspect the camshaft gear teeth for pitting.



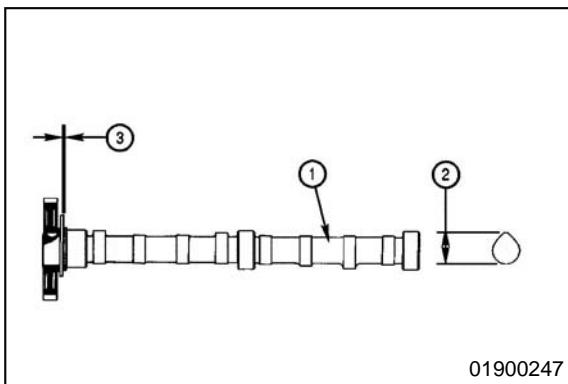
Inspect for cracks at the roots of the teeth.



Measure the outside diameter of camshaft bearing journals.



Journal	Standard Size	Tolerance		Standard Clearance	Clearance Limit
		Shaft	Hole		
Number1, Number2, and Number3	50.5 mm [2.00 in]	-0.080 to -0.110 mm [-0.003 to -0.004 in]	+0.030 to -0.040 mm [0.001 to -0.002 in]	0.040 to 0.140 mm [0.016 to 0.006 in]	0.25 mm [0.010 in]



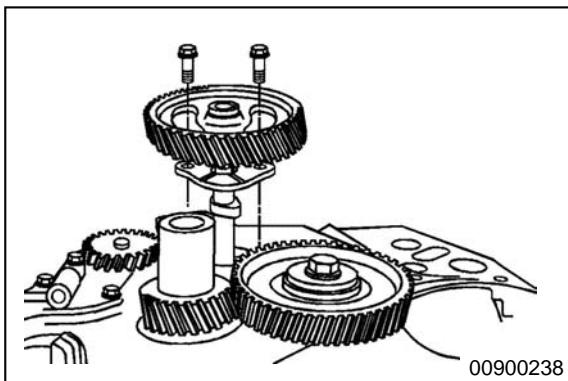
Measure the bend (1) of the camshaft.

Bend of Camshaft		
Mm	in	
0.03	MAX	0.0012

Measure the camshaft lobe height (2) and thrust clearance (3).

Camshaft Lobe Height		
	Valves	Standard MIN
2	Intake	42.69 mm [1.681 in]
	Exhaust	43.04 mm [1.694 in]
		Repair Limits MAX
		42.20 mm [1.661 in]
		42.50 mm [1.673 in]

Thrust Clearance		
	Standard MIN	Repair Limits MAX
3	0.150 to 0.350 mm [0.0059 to 0.0138 in]	0.50 mm [0.0197 in]

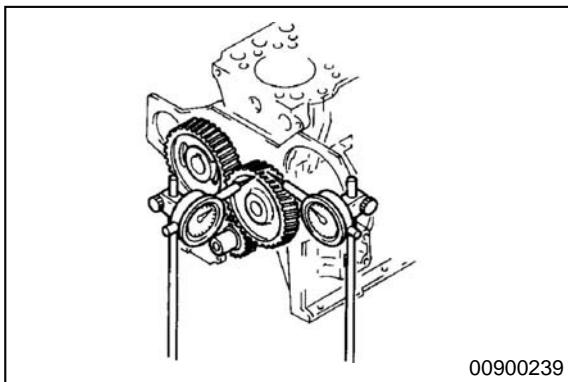


NOTE: When installing the camshaft, rotate the camshaft slightly while being careful not to damage the bushing.

Install the thrust plate, camshaft assembly, and two capscrews.

Tighten the capscrews through the casting holes in the camshaft gear.

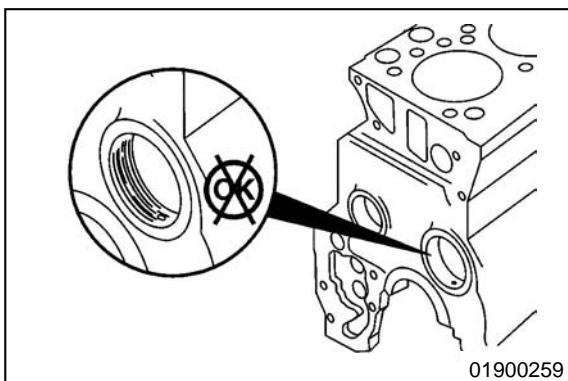
Torque Value: 19 N·m [14 ft-lb]



Measure the end play of the camshaft.

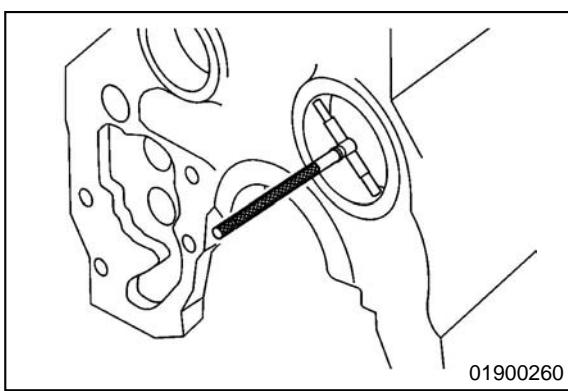
Camshaft End Play		
Mm	in	
0.150	MIN	0.0059
0.350	MAX	0.0138

Camshaft Bushings



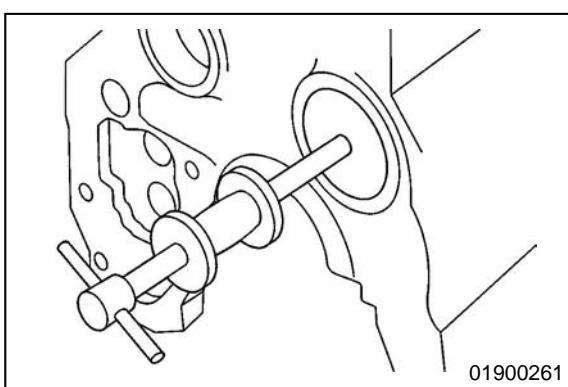
Initial Check

Inspect the camshaft bore for damage and excessive wear.

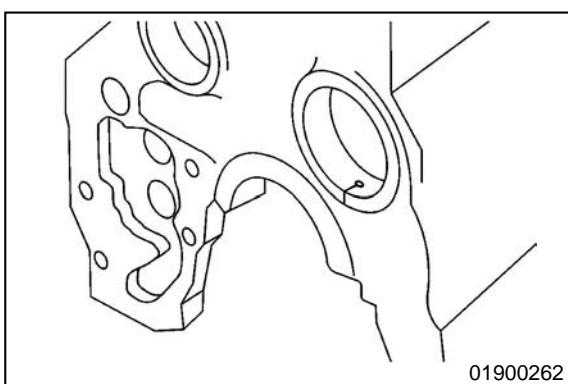


Measure the camshaft bore.

Camshaft Bore Diameter		
Mm	in	
53.53	MAX	2.107

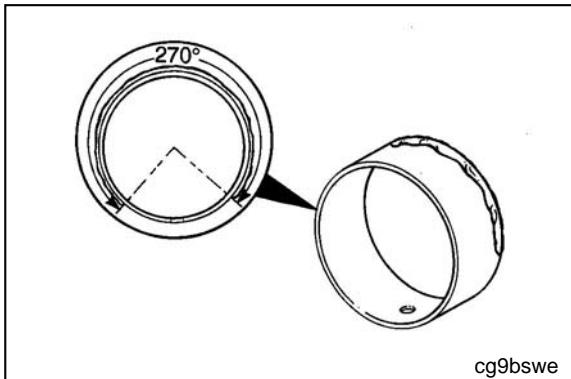


Use a small bushing driver set, Part Number 3823942, or equivalent, to remove the camshaft bushing from the number 1 camshaft bore.



NOTE: Make sure the camshaft bore in the cylinder block and the outside diameter of the bushing are clean of oil and dirt.

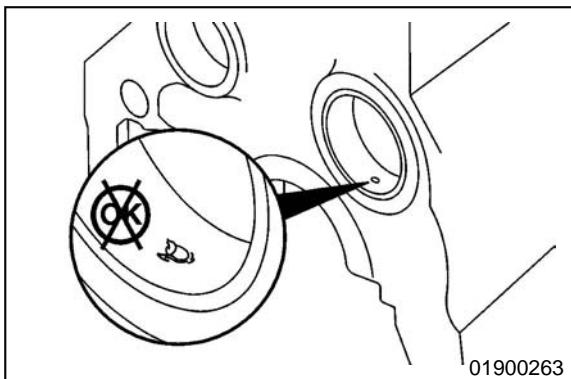
Mark the camshaft bushing and cylinder block and align the lubricating oil hole in the cylinder block with the lubricating hole in the camshaft bushing.



Apply Loctite primer to the outside diameter of the camshaft bushing and the inside of the camshaft bore of the cylinder block.

Allow the primer to dry.

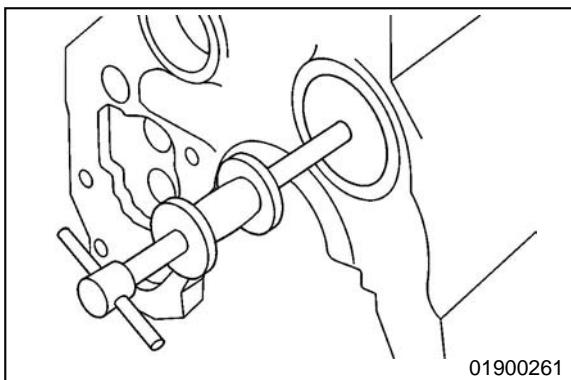
Apply a bead of Loctite 609, or equivalent, to 270 degrees along the edge of the bushing that will be installed toward the rear of the cylinder block.



⚠ CAUTION

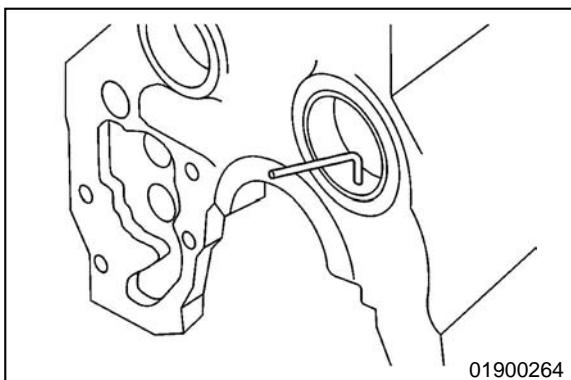
Make sure there is no Loctite in the oil hole, or severe engine damage can occur.

Use extreme care not to apply Loctite to the oil hole in the camshaft bushing.



Use a small camshaft bushing driver set, Part Number 3823942, or equivalent, to install the camshaft bushing even with the front face of the cylinder block.

Use a clean, lint-free cloth to wipe off any excessive Loctite.

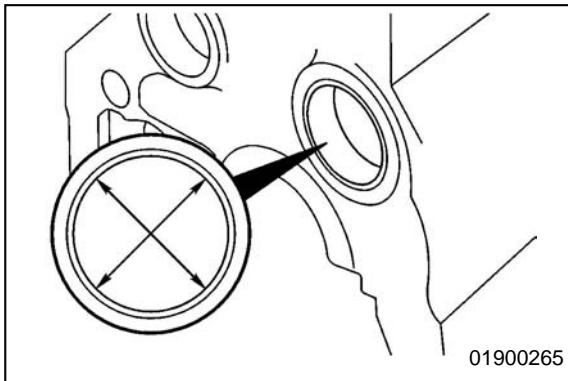


⚠ CAUTION

Make sure there is no Loctite in the oil hole, or severe engine damage can occur.

Make sure the lubricating oil hole in the camshaft bushing is aligned with the camshaft oil hole in the cylinder block.

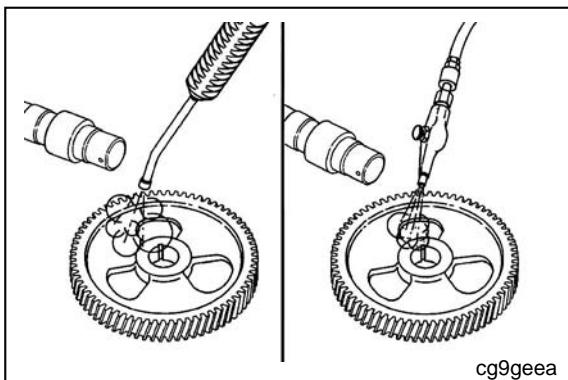
A 3.2-mm [0.126-in] diameter rod must be able to pass through the lubricating oil hole.



Measure the installed camshaft bushing (1).

Camshaft Bushing Bore Inside Diameter		
Mm	in	
50.50	MIN	1.988
53.60	MAX	1.992

Camshaft Gear



⚠️ WARNING



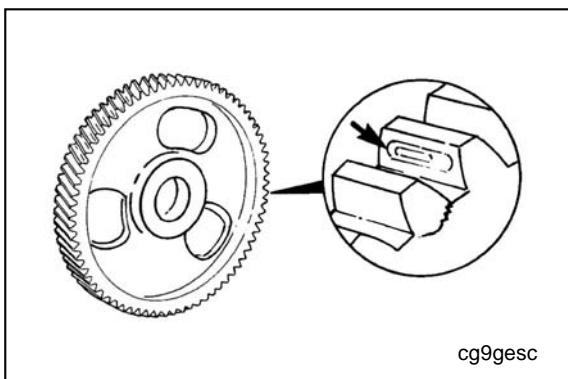
When using solvents, acid, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠️ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use solvent to clean the camshaft gear.

Dry with compressed air.



NOTE: If nicks or burrs can not be removed with abrasive pad, Part Number 3823258, or equivalent, replace the camshaft and camshaft gear. Refer to Procedure 001-008 for camshaft removal.

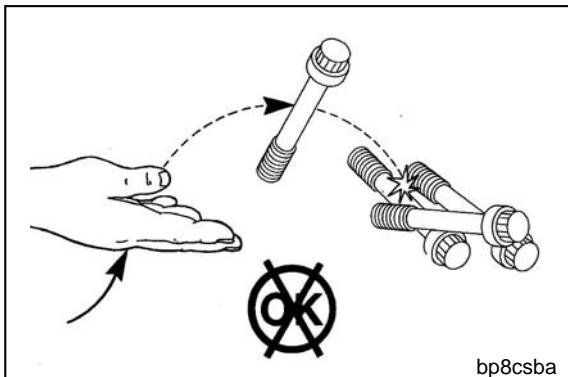
Inspect the camshaft gear for cracked, chipped, or broken teeth.

Inspect the camshaft gear teeth for discoloration or signs of excessive heat (bluing).

If any damage is present, replace the camshaft and camshaft gear. Refer to Procedure 001-008 for camshaft removal.

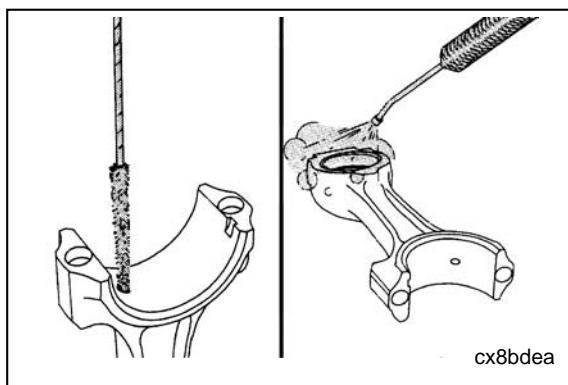
NOTE: If there is damage to the camshaft gear teeth or there are signs of excessive heat, make sure to inspect the associated idler and oil pump gears for damage.

Connecting Rod



⚠ CAUTION

Prevent damage to the capscrews. Nicks in the body of the capscrew can cause an area of stress that can fail during engine operation. Damage to the threads will cause torque values to be incorrect and will damage the mating parts.



⚠ WARNING

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious injury.

⚠ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

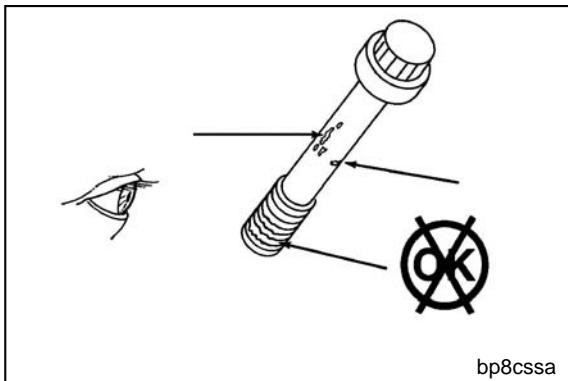
⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent or steam to clean the capscrews, connecting rod, and connecting rod cap.

Dry with compressed air.

Use a soft bristle brush to clean the oil drilling.



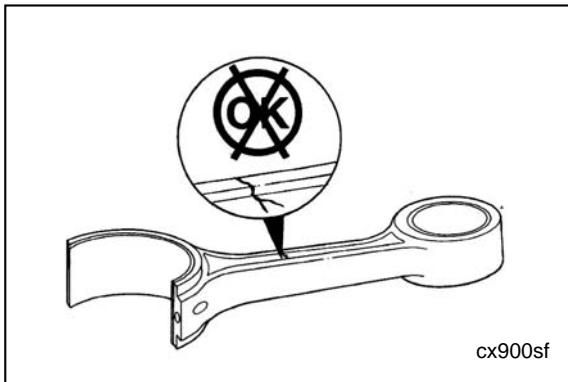
⚠ CAUTION

Repair of rolled threads by use of a thread die is not recommended. The die can create a sharp corner on the minor diameter (root) of the threads. This sharp corner can cause an area of increased stress.

Inspect the capscrews for the following:

- Damaged threads
- Rust or corrosion-caused pitting
- Nicks, bent, stretched, or galled.

The capscrew must be replaced if it has any of the listed damage.

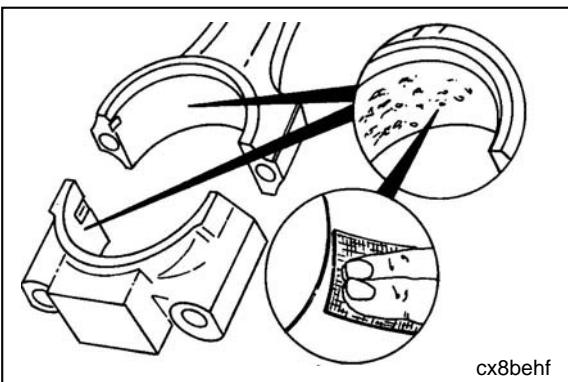


Inspect the connecting rod and connecting rod cap for damage.

Replace the connecting rod if the I-beam or connecting rod cap is damaged.

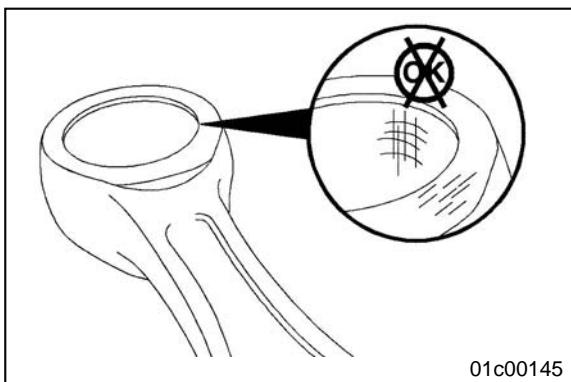
Inspect the connecting rod and connecting rod cap for fretting damage on the mating surfaces.

The connecting rod and connecting rod cap must be replaced as an assembly if fretting damage is visible on either piece.



Check the bearing surface for nicks or burrs.

If it is not possible to remove any nicks or burrs with a fine emery cloth, the connecting rod must be replaced.

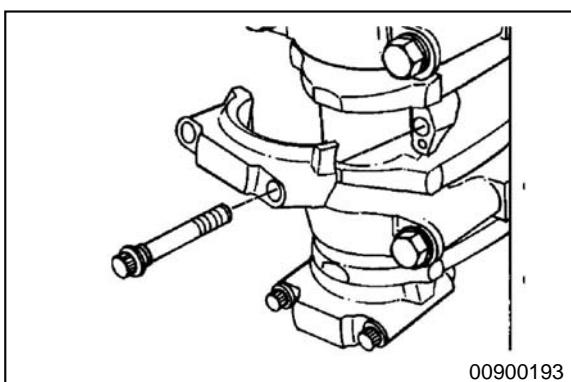


Inspect the connecting rod piston pin bushing for damage.

Replace any connecting rod piston pin bushing that has evidence of scoring, galling, or scuffing.

Replace any bushing that has turned in the bore.

Special tools and precision machining are required to replace bushings. If Cummins Inc. approved tools and procedures are not available, the connecting rod must be replaced.



⚠ CAUTION

The connecting rod cap numbers must match the numbers on the connecting rod and must be installed with the characters aligned to prevent damage to the connecting rods and crankshaft.

⚠ CAUTION

Use a vise with brass jaws to hold the connecting rod. Notches, scratches, or dents in the I-beam area can cause engine failure.

Place the connecting rod into a vise with brass jaws.

Install the connecting rod cap onto the connecting rod.

Lubricate the threads of the capscrews with clean engine oil.

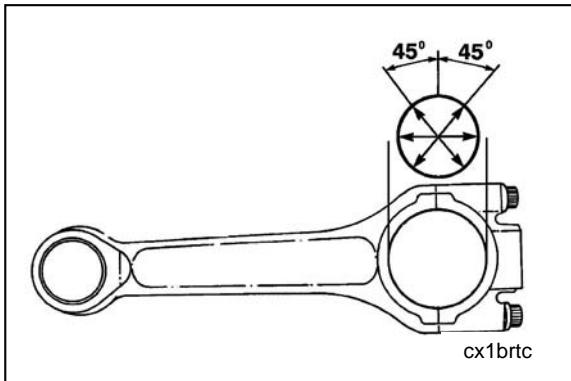
Thread the capscrews into the connecting rod and hand tighten.

Tighten the capscrews.

Torque Value:

Step 1 39 n.m [29 ft-lb]

Step 2 Rotate each capscrew 90 degrees.

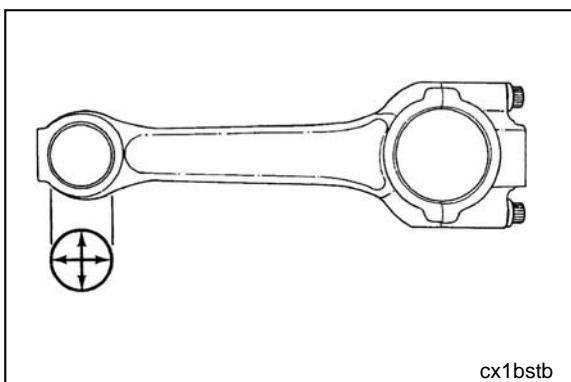


Measure the connecting rod crankshaft bore inside diameter with a bore dial indicator.

Connecting Rod Crankshaft Bore Inside Diameter

Mm		in
61.00	MIN	2.402
61.025	MAX	2.403

If the connecting rod crankshaft bore inside diameter is not within specifications, the connecting rod must be replaced.

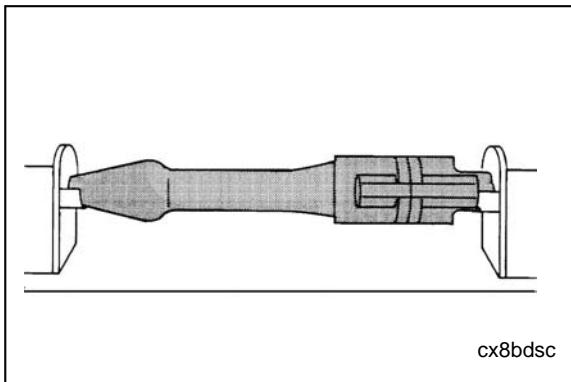


Measure the connecting rod piston pin bushing inside diameter.

Connecting Rod Piston Pin Bushing Inside Diameter

Mm		in
33.00	MIN	1.299
33.025	MAX	1.300

If the connecting rod crankshaft bore inside diameter is not within specifications, the connecting rod must be replaced.



This procedure describes the magnetic particle inspection for the connecting rod and connecting rod cap.



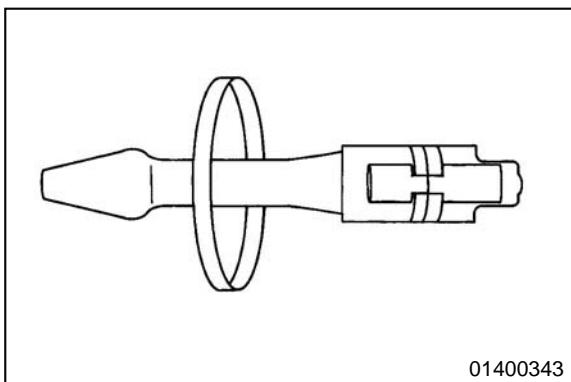
Use a magnetic particle testing machine.

The connecting rod and connecting rod cap must be assembled during this process.

Use the residual method. Apply head shot amperage. Adjust the amperage to 1500 ampere direct current or rectified alternating current.

Check for cracks.

The connecting rod must be replaced if any cracks are visible.



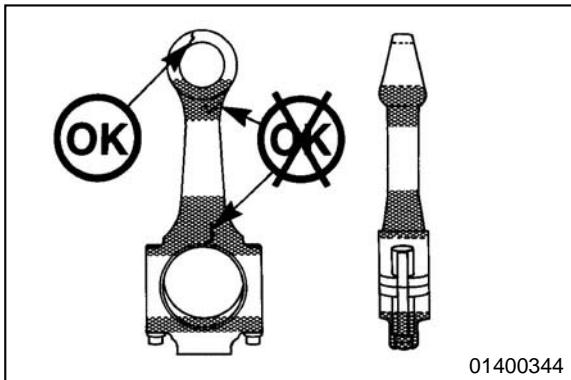
Use the residual method. Apply coil shot amperage.



Amperage (Ampere Turns)

Minimum	Maximum
2600 amperage direct current	2800 amperage direct current

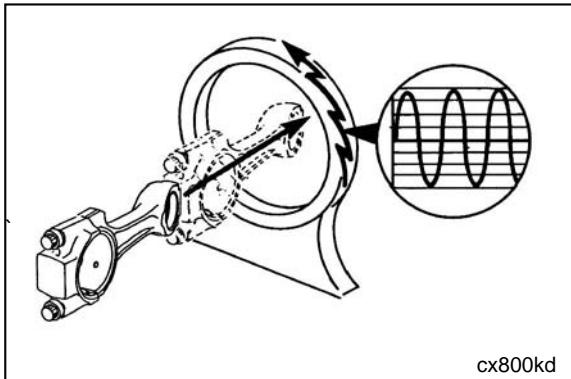
Ampere turn is an electrical current of one ampere flowing through the coil, multiplied by the number of turns in the coil.



Check for cracks.



The connecting rod must be replaced if any indications are visible in the critical (shaded) areas.



⚠️ WARNING

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious injury.

⚠️ WARNING

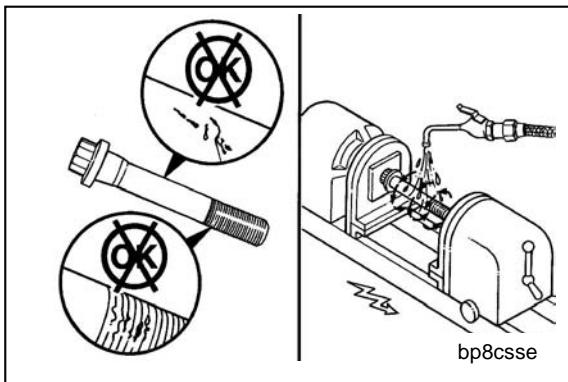
When using solvents, acids, or alkaline materials for cleaning, follow manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ CAUTION

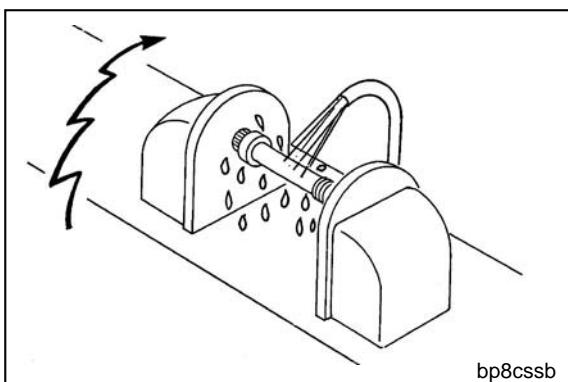
The connecting rod must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the connecting rod.

Use solvent or steam to clean the connecting rod.

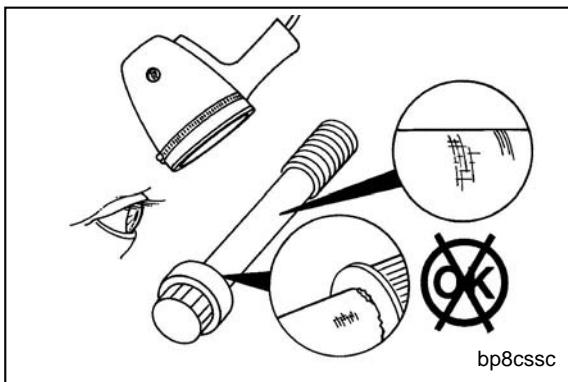


This procedure describes the magnetic particle inspection for connecting rod capscrews.



Use a Magnaflux or similar magnetic particle testing machine.

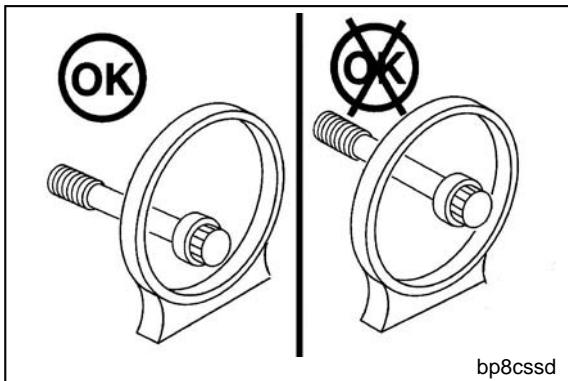
Use the continuous method. Apply a head shot of 300 to 400 amperes direct current or rectified alternating current.



Use an ultraviolet light. Check for indications of cracks.

The magnetic particles tend to form on sharp corners and edges. Do not mistake these for cracks.

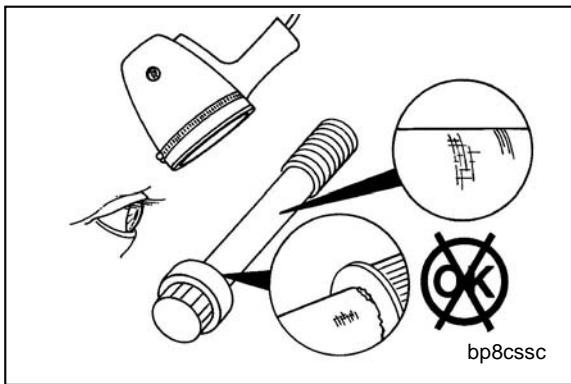
Any indications of cracks are not acceptable.



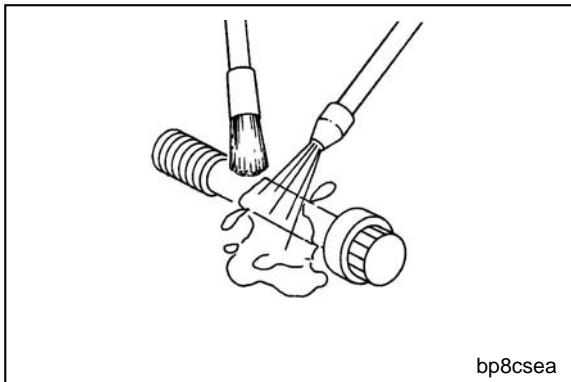
Prepare the machine for a coil shot.

Make sure the capscrew is near one side of the coil and not in the center.

Apply 1000 to 1350 ampere-turns.



Use an ultraviolet light. Check for indications of cracks.
Any indications of cracks are not acceptable.



⚠ WARNING

When using solvents, acids or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.



Wear eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

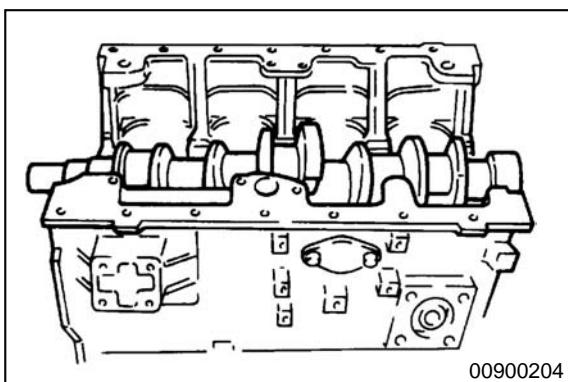


The capscrew must be demagnetized completely and cleaned thoroughly. Any small metal particles will cause engine damage.

Demagnetize the capscrew thoroughly.

Use solvent to clean the capscrew and dry with compressed air.

Crankshaft



WARNING

This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

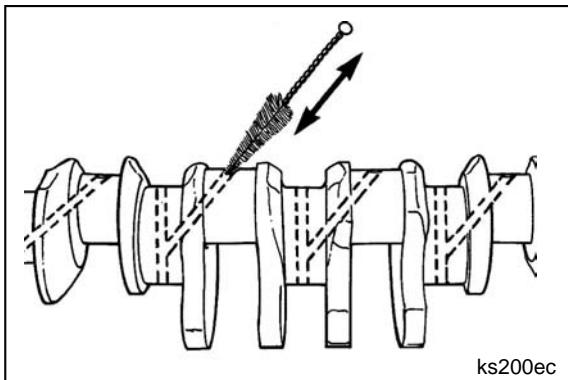


CAUTION

Be careful not to hit the crankshaft against the cylinder block and damage the sliding surface.

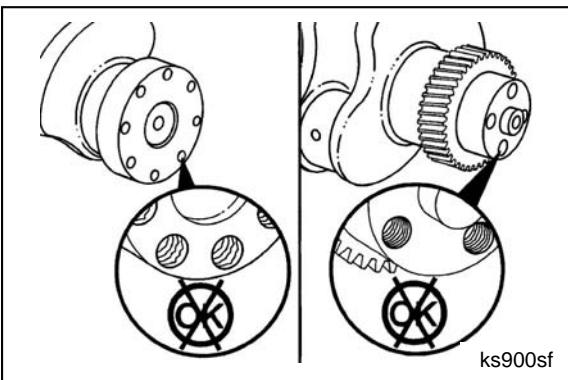
Remove the main bearings. Refer to Procedure 001-006.

Remove the crankshaft from the cylinder block.



Use fine crocus cloth to polish the machined surfaces.

Use a bristle brush to clean the oil drillings.

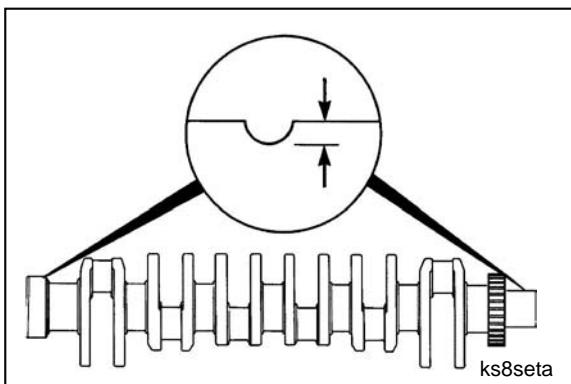


NOTE: If more than two threaded holes are damaged in one end, the crankshaft must be replaced.

Inspect the threaded capscrew holes for damage.

Use one of the following methods to repair any threaded holes:

- Chase the threads
- Use the threaded insert kit, Part Number 3822709, or equivalent.



Measure the front and rear oil seal contact areas for a wear groove.

Crankshaft Front and Rear Oil Seal Wear Groove

Mm

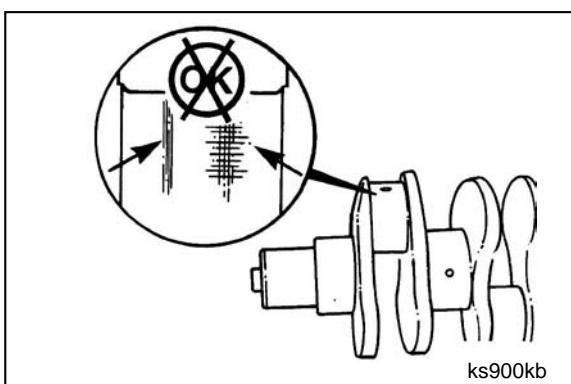
in

0.25

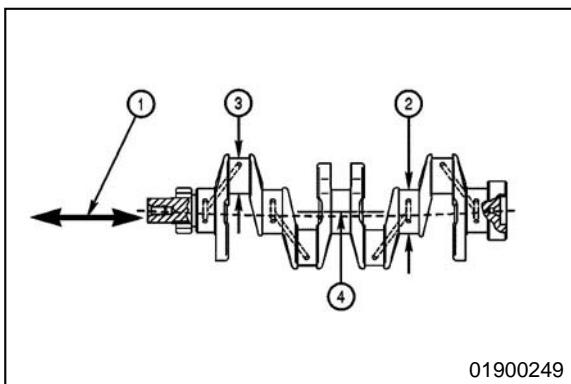
MAX

0.010

If the wear groove exceeds the specification, replace the crankshaft.



Inspect the crankshaft connecting rod and main journals for deep scoring, overheating, or other damage.

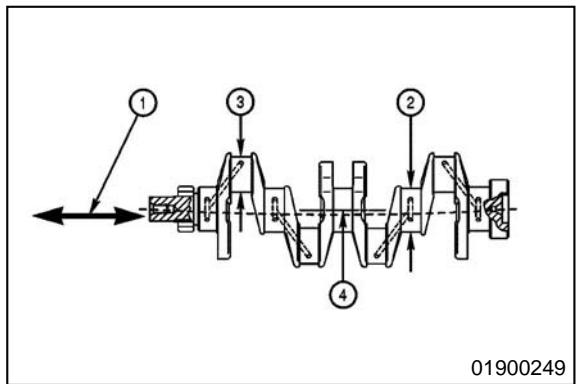


NOTE: Oversize thrust bearings are available if the thrust distance is not within specifications. If the crankshaft must be machined to use an oversize thrust bearing, refer to the Alternative Repair Manual, Bulletin 3379035, for machining instructions.

Measure the thrust clearance (1).

Crankshaft installed or crankshaft thrust width minus block thrust width + bearing width.

Crankshaft Thrust Clearance		
Mm		in
0.131	MIN	0.0052
0.351	MAX	0.0138



Measure the main journal (2).



Connecting Rod Bearing Journal Diameter

	mm	in
Standard	69.86	MIN 2.750
	70.00	MAX 2.756
0.25mm	69.61	MIN 2.741
	69.75	MAX 2.746
0.50mm	69.36	MIN 2.731
	69.50	MAX 2.736
0.75mm	69.11	MIN 2.721
	69.25	MAX 2.726
1.00mm	68.86	MIN 2.711
	69.00	MAX 2.717

Bearing Clearance (2) = Main bearing inside diameter with bearing installed minus crankshaft journal diameter. Refer to procedure 001-026.

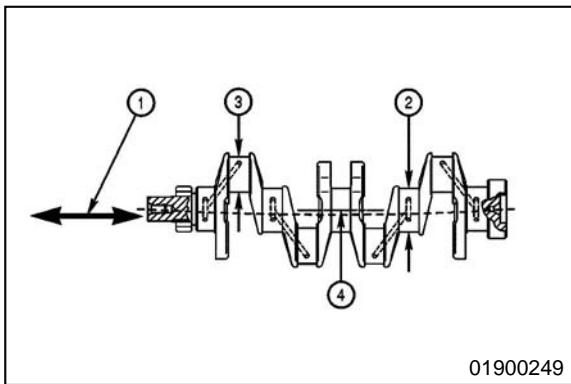
Measurements		
	mm	in
Bearing Clearance	0.043 to 0.103	[0.0017 to 0.0041]

Check the roundness (2) of the bearing journal.

Connecting Rod Bearing Journal		
	mm	in
Out-of-Roundness	0.020	MAX 0.0008

Measure the connecting rod crankshaft pin journal (3).

	mm	in
Standard	56.91	MIN 2.241
	57.00	MAX 2.244
0.25 mm	56.66	MIN 2.231
	56.75	MAX 2.234
0.50 mm	56.41	MIN 2.221
	56.50	MAX 2.224
0.75 mm	56.16	MIN 2.211
	56.25	MAX 2.215
1.00 mm	55.91	MIN 2.201
	56.00	MAX 2.205



Measure the clearance of the crankshaft pin journal (3)



Measurements

	mm	in
Bearing Clearance	0.029 to 0.089	0.0011 to 0.0035

Check the roundness (3) of the connecting rod crankshaft pin journal.

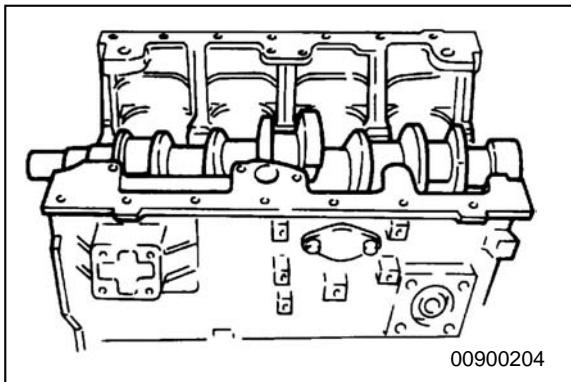
Connecting Rod Crankshaft Pin Journal

	mm	in
Out-of-Roundness	0.020 MAX 0.0008	

Measure the bend of the crankshaft (4).

Measurements

	mm	in
Crankshaft Bend	0.09	0.0035



WARNING

This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.



CAUTION

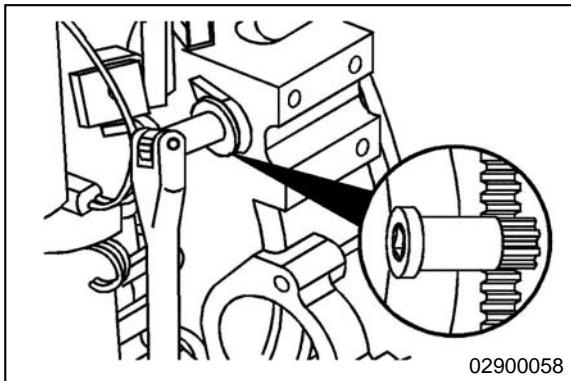
Do not hit the crankshaft against the cylinder block. Failure to do so can result in damage to the block or crankshaft.

Lubricate the upper main bearings with clean engine lubricating oil.

Install the upper main bearings. Refer to Procedure 001-006.

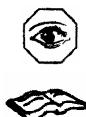
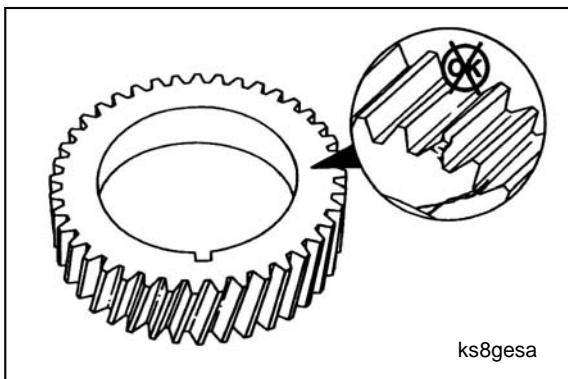
Position and install the crankshaft and gear into the cylinder block.

Install the lower main bearings and bearing caps. Refer to Procedure 001-006



NOTE: The crankshaft must rotate freely by hand.

Crankshaft Gear, Front



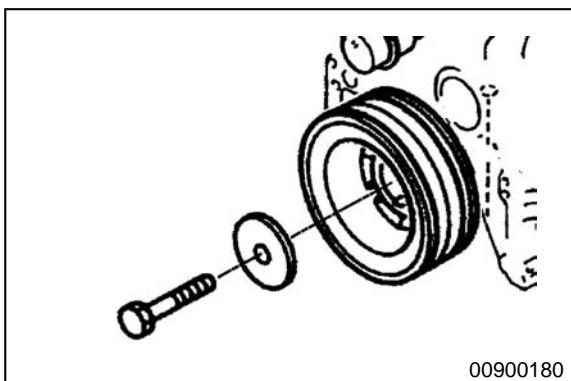
NOTE: If there is damage to the front crankshaft gear teeth or there are signs of excessive heat, make sure to inspect the associated idler gear for damage.

Inspect the crankshaft gear teeth for discolorations or signs of excessive heat (bluing).

Inspect for cracks and broken or chipped teeth.

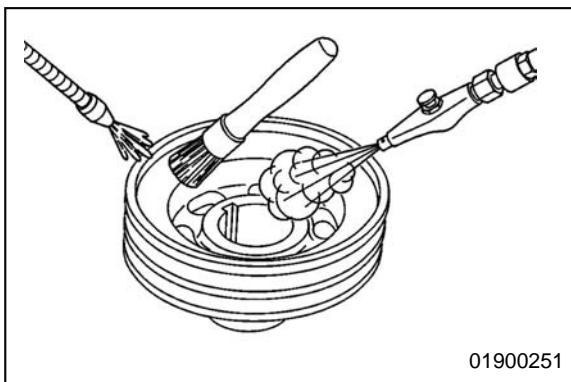
If any damage is present, replace the crankshaft and crankshaft gear. Refer to Procedure 001-016 for crankshaft removal.

Crankshaft Pulley



Remove the capscrew and mounting plate.

Use a standard puller, Part Number ST 647, or equivalent, to remove the crankshaft pulley.



⚠️ WARNING

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ WARNING

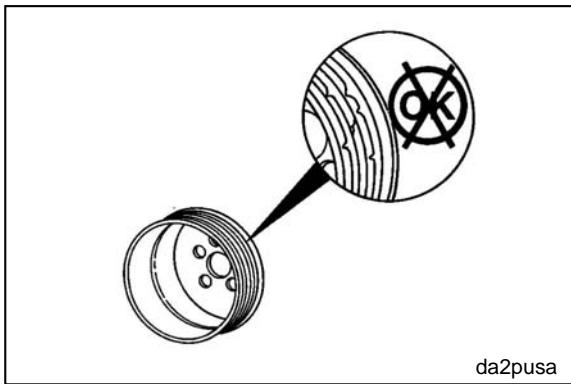
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠️ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

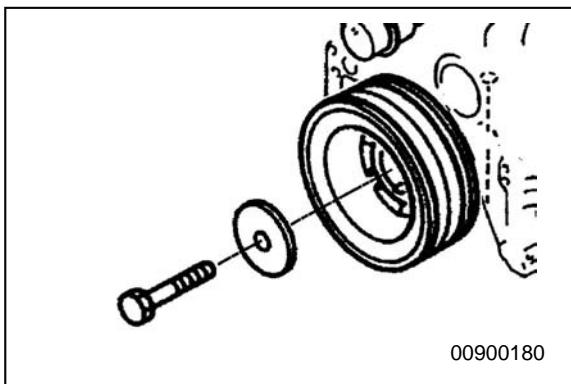
Clean the crankshaft pulley with steam or solvent.

Dry with compressed air.



Inspect the pulley for cracks, excessive wear in the belt grooves, or other damage.

Inspect the mating surface and pulley bore areas for damage.



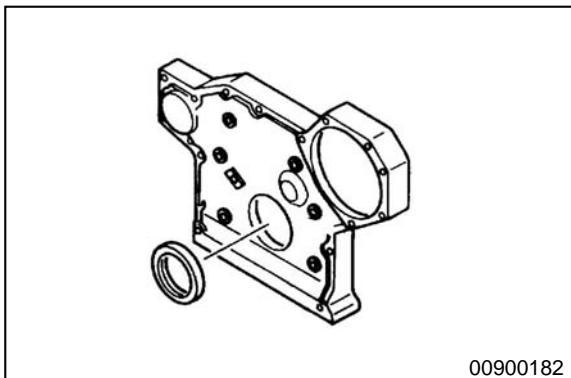
Align the crankshaft pulley with the crankshaft key.

Install the crankshaft pulley, mounting plate, and capscrew.

Tighten the capscrew.

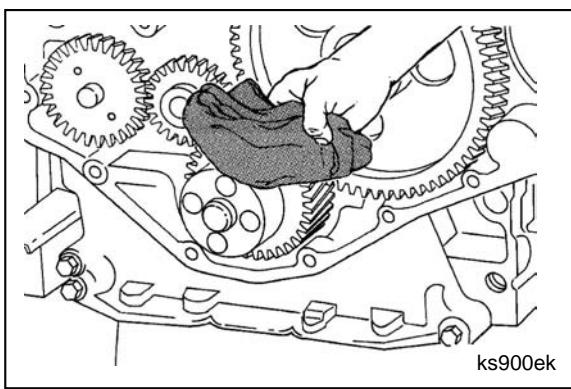
14mm Capscrew With PTO	176 n.m	[130 ft lb]
14 mm Capscrew Without PTO	93 n.m	[69 ft lb]
18 mm Capscrew All	372 n.m	[274 ft lb]

Crankshaft Seal, Front

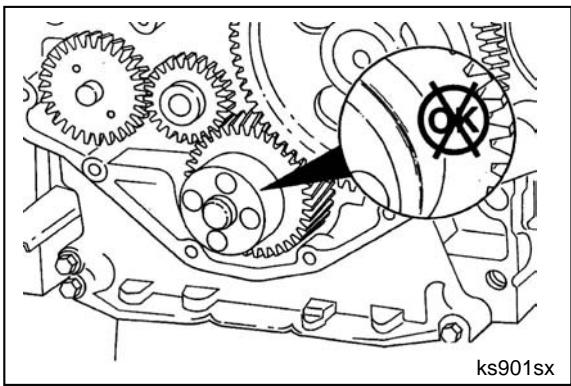


NOTE: A noise dampener is installed on some engines. The noise dampener must be removed prior to removing the front crankshaft seal.

Use a pry bar or suitable tool to remove the front crankshaft seal from the front gear cover.



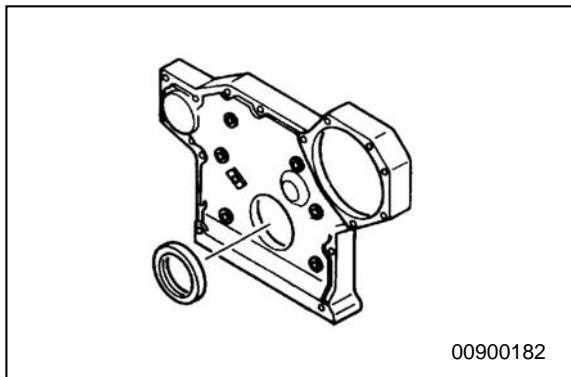
Clean the gear cover seal bore and crankshaft surface of all oil, dirt, and seal residue.



NOTE: If the crankshaft has excessive wear, the crankshaft must be replaced.



Inspect the crankshaft for excessive wear.



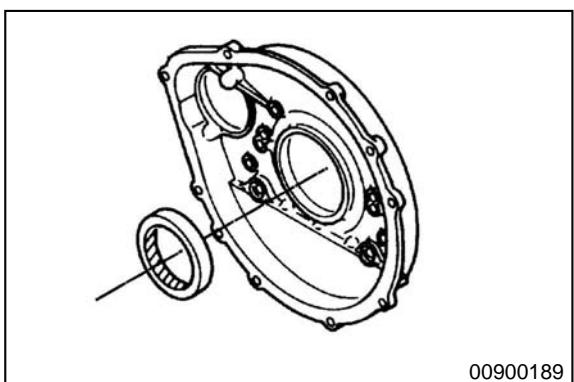
Fill 40 to 60 percent of the space in the seal lip with grease.



Use a crankshaft seal installer, Part Number 3164900, or equivalent, to install the seal in the front gear cover.

Install the noise dampener, if equipped.

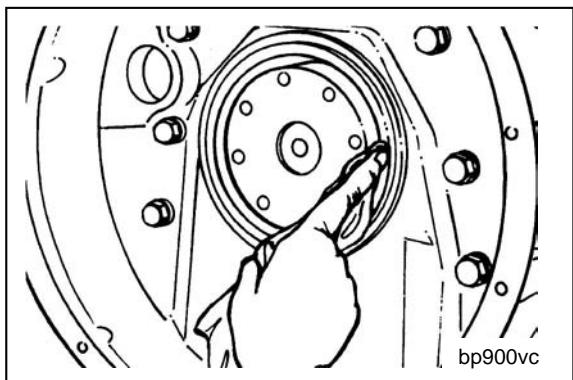
Crankshaft Seal, Rear



Use a pry bar or suitable tool to remove the rear crankshaft seal.



00900189



CAUTION

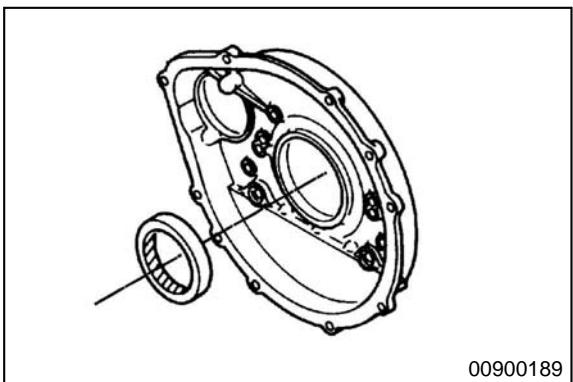


The seal lip and the sealing surface on the crankshaft must be free from all residue to reduce the possibility of seal leaks.

Clean and dry the rear crankshaft sealing surface.

Clean and dry the flywheel housing seal bore.

Inspect the crankshaft sealing area and flywheel housing bore for burrs or raised material. Remove the burrs or raised material with crocus cloth.

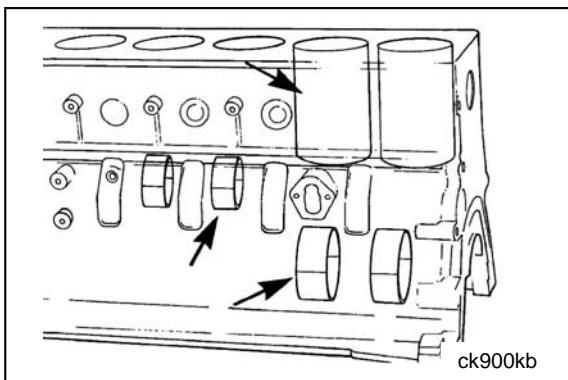


Fill 40 to 60 percent of the space in the seal lip with grease.

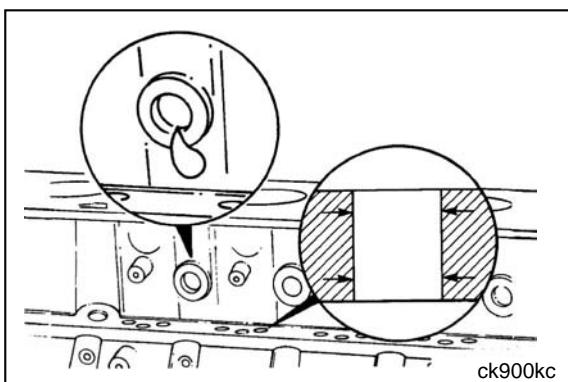


Use crankshaft seal installer, Part Number 3164900, or equivalent, to install the crankshaft seal.

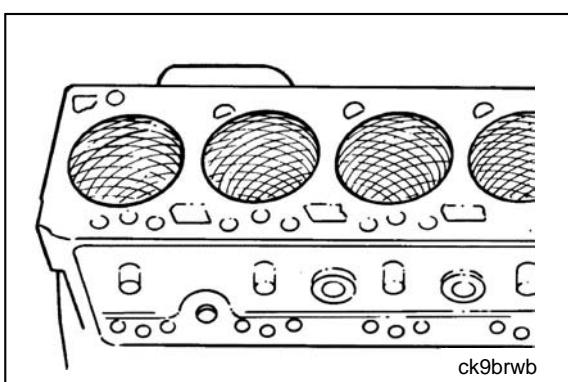
Cylinder Block



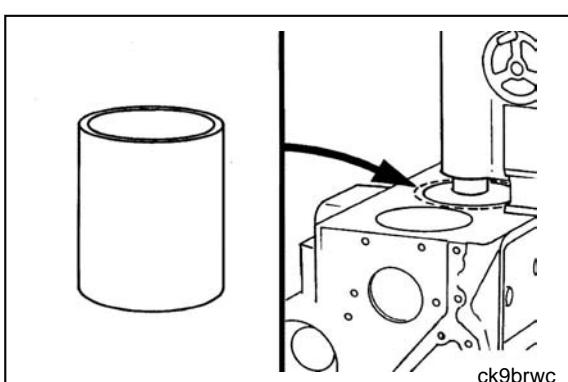
Diagnosis of cylinder block cooling and lubrication malfunctions has been discussed in those respective sections. The potential problems with the cylinder, the camshaft bore, and the crankshaft main journals are discussed in this section.



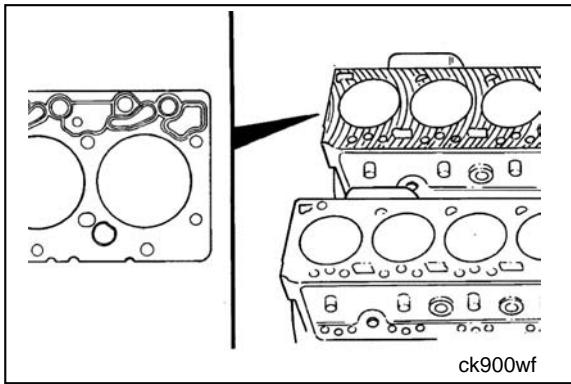
 Malfunctions of the cylinder block, such as leaks or tappet bore wear, require a visual or dimensional inspection to isolate the problem.



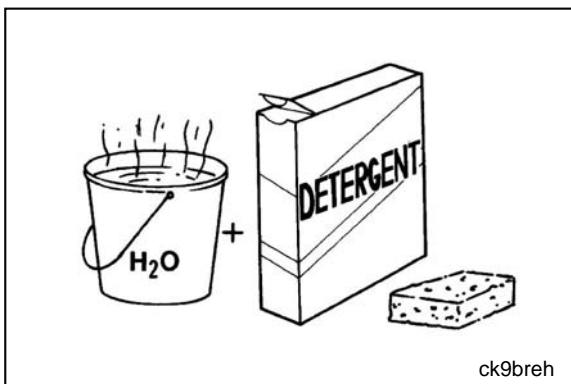
 The cylinder bores are machined directly into the cylinder block during production. The size and condition of the cylinder bore is critical to engine performance and life. During repair, make sure to inspect the cylinder bores carefully. It will also be necessary to deglaze the cylinder walls before reassembly. A 30-degree crosshatch pattern is needed to seat the new piston rings.



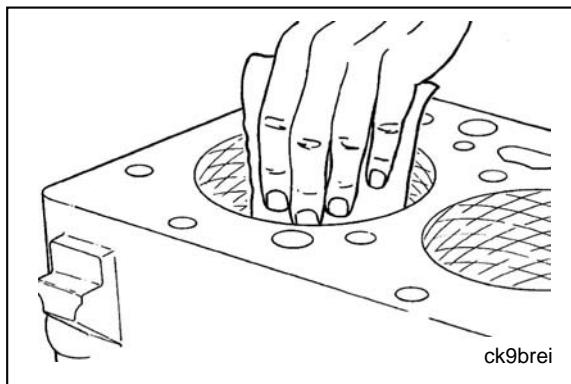
 The cylinder bores can be rebored in a machine shop and fitted with an oversize service piston.



The head surface of the block is also critical to sealing the cylinder bores. Inspect the surface carefully during repair before assembly.



Use a strong solution of hot water and laundry detergent to clean the cylinder bores.



⚠️ WARNING

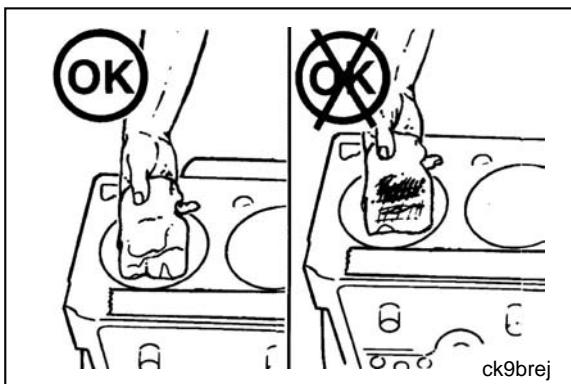
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

⚠️ CAUTION

Clean the cylinder bores immediately after deglazing, or premature wear of the bores and rings can result.

Rinse the cylinder bores until the detergent is removed.

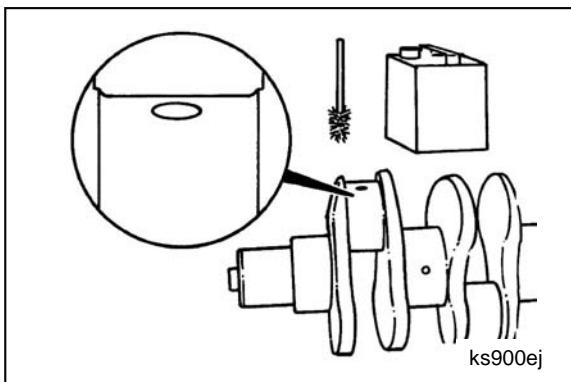
Dry the cylinder block with compressed air.



NOTE: Make sure to remove the tape covering the tappet and lubricating oil holes after the cleaning process is complete.



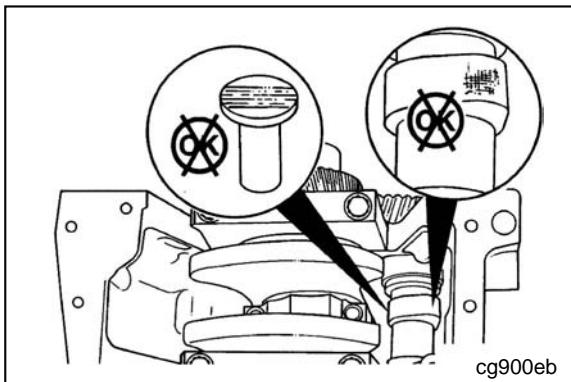
Check the cylinder bore cleanliness by wiping with a white, lint-free, lightly oiled cloth. If grit residue is still present, repeat the cleaning process until all residue is removed.



NOTE: Make sure to remove the covering from the piston cooling nozzles.



Remove the protective tape and cloth, and clean the crankshaft journals.



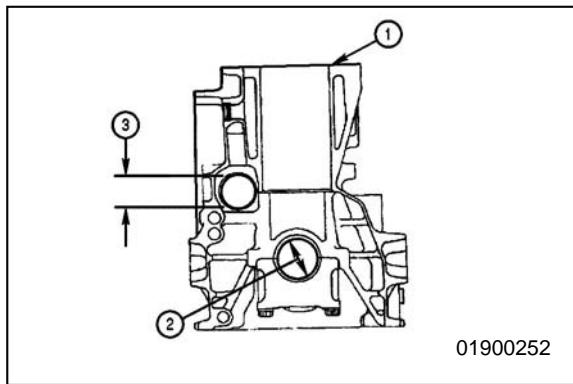
⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a solvent and a brush to clean any residue that possibly has splashed on the camshaft.

Inspect the camshaft lobes and tappet faces for signs of wear or damage. Refer to Procedure 001-008.



Measure the surface flatness (1)(warpage limit).

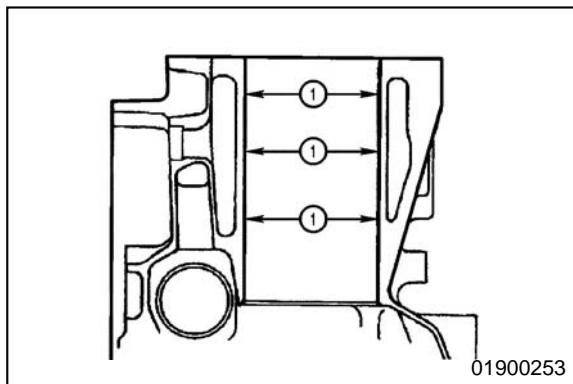
Surface Flatness	
Standard	Repair Limit
0.00 to 0.08 mm [0.00 to 0.003 in]	0.15 mm [0.006 in]

Measure the inner diameter of the main bearing (2).

Inner Diameter of Main Bearing (Bearing Installed)			
	mm	in	
Standard	70.00	MIN	2.756
	70.20	MAX	2.764
0.25	69.25	MIN	2.726
	69.75	MAX	2.746
0.50	69.50	MIN	2.736
	69.70	MAX	2.744
0.75	69.25	MIN	2.726
	69.45	MAX	2.734
1.00	69.00	MIN	2.717
	69.20	MAX	2.724

Measure the inner diameter of the camshaft bushing (3).

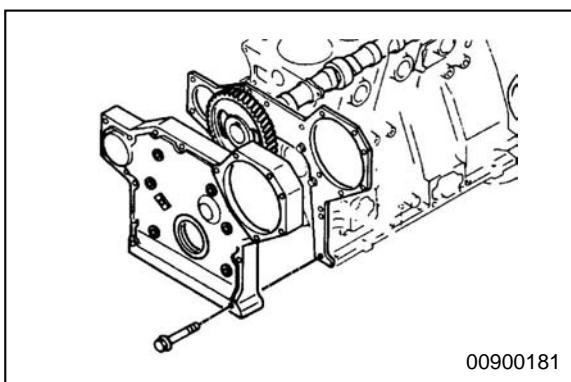
Camshaft Bushing Inside Diameter	
Standard	Repair Limit
50.50 mm [1.988 in]	50.60 mm [1.992 in]



Measure the cylinder bore (1).

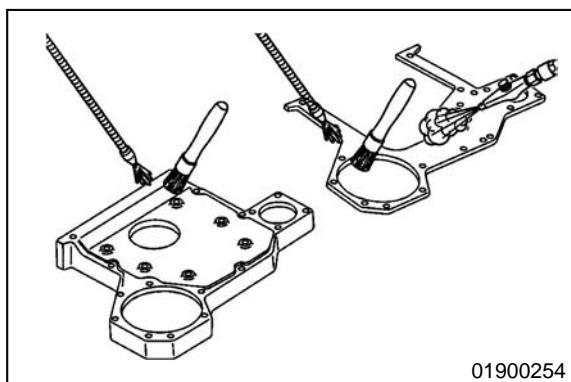
Cylinder Bore Dimensions			
	Inside Diameter	Tolerance	Repair Limit
Standard Bore	95.00 mm [3.740 in]	0.022 mm [0.0008 in]	95.15 mm [3.746 in]
Out of Roundness	N/A	N/A	0.02 mm [0.0008 in]
Taper	N/A	N/A	

Gear Cover, Front



Remove the 17 capscrews, front gear cover, cover plate, and gasket.

Discard the gasket.



⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ WARNING

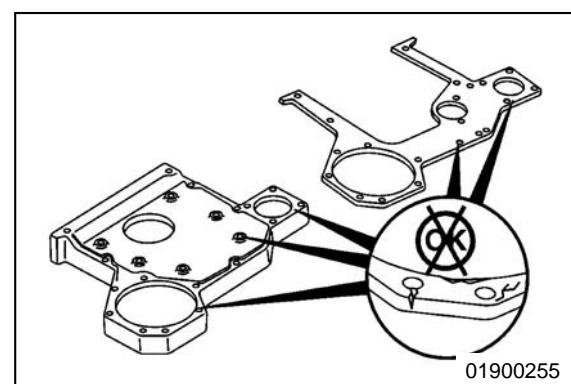
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠️ WARNING

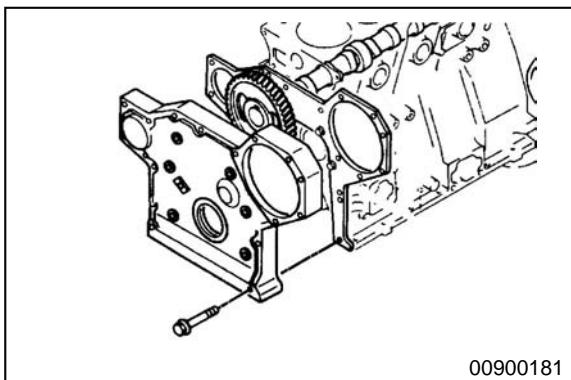
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the front gear cover and cover gasket surface with solvent. Dry with compressed air.

Clean the cylinder block gasket surface.



Inspect the front gear cover and cover plate for cracks or other damage.



⚠ CAUTION

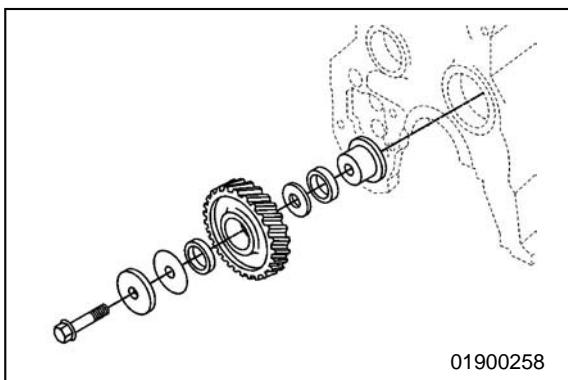
Apply gasket sealant, Part Number 3164067, or equivalent, to the gear cover mounting surface.



Install the new gasket, gear cover, and 17 capscrews. Tighten the capscrews.

Torque Value: 19n.m [14 ft-lb]

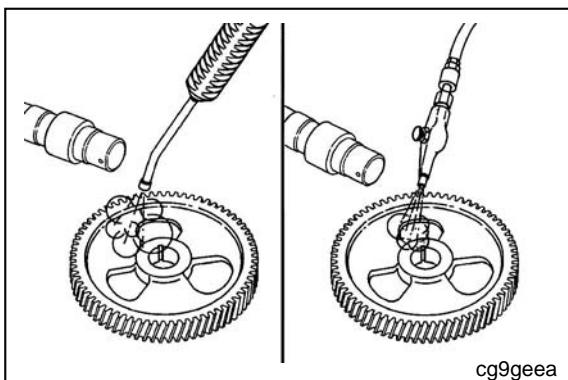
Idle Gear, Camshaft



NOTE: If a PTO accessory drive is used on the engine, the idler gear uses two bearings.

Remove the capscrew, plate, shim, and front bearing.

Remove the idler gear, rear spacer plate, rear bearing, and idler shaft.



⚠ WARNING

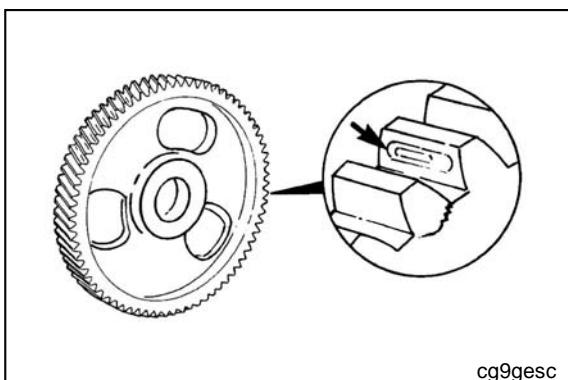
When using solvents, acid, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.



Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use solvent to clean the idler gear.

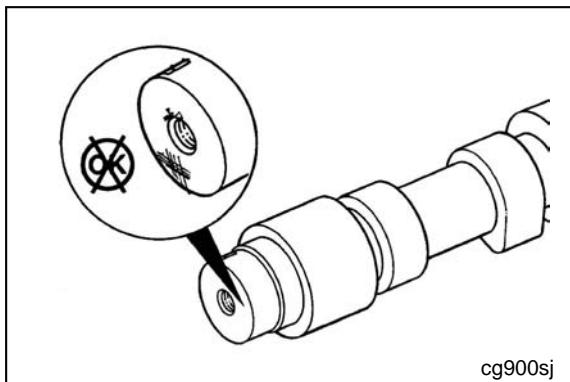
Dry with compressed air.



NOTE: If the burrs or raised material can not be removed with an abrasive pad, or equivalent, the camshaft idler gear must be replaced.

Inspect the idler gear for cracked, chipped, or broken teeth.

Inspect the idler shaft bore for burrs.

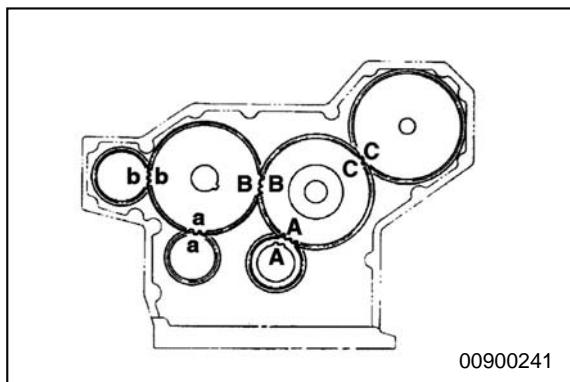


NOTE: If the burrs or raised material can not be removed with an abrasive pad, or equivalent, the camshaft idler gear shaft must be replaced.

Inspect the idler shaft nose for burrs.

Always connect the negative (-) cable last.

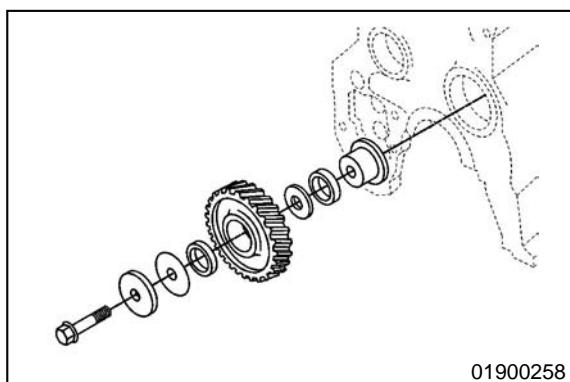
Connect the battery cables.



Align the match marks on the idler gear, crankshaft gear, and camshaft gear. The match marks are identified as follows:

- A. Crankshaft gear and idler gear
- B. Idler gear and camshaft gear
- C. Fuel pump and idler gear

NOTE: Lower case letters identify oil pump and accessory drive, which are not timed.

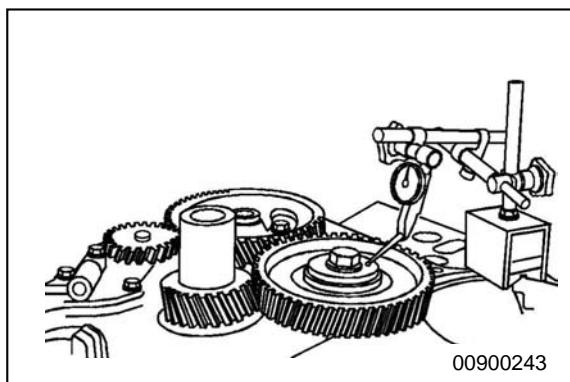


NOTE: If a PTO accessory drive is used on the engine, the idler gear uses two bearings.

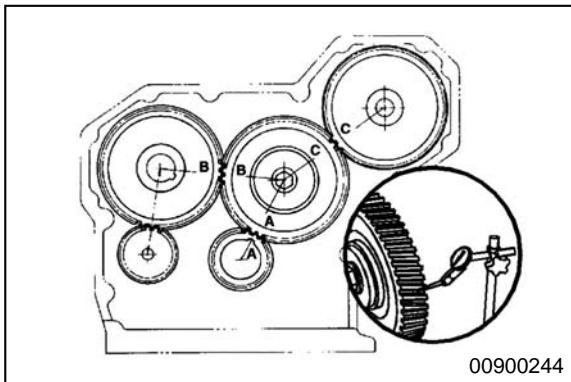
Install the idler shaft, rear bearing, rear spacer plate, and idler gear.

Install the front bearing, plate, shim, and capscrew. Tighten the capscrew.

Torque Value: 110 n.m [81 ft-lb]



Measure the end play of the idler gear.

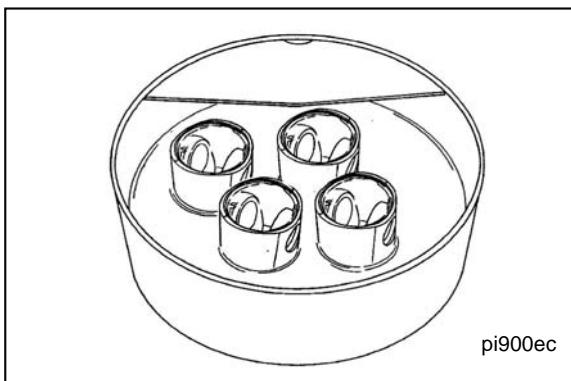


Position the fuel injection pump assembly temporarily.

Measure the backlash of each gear with a dial indicator, 3376050, or equivalent.



Piston



⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ WARNING

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠️ CAUTION

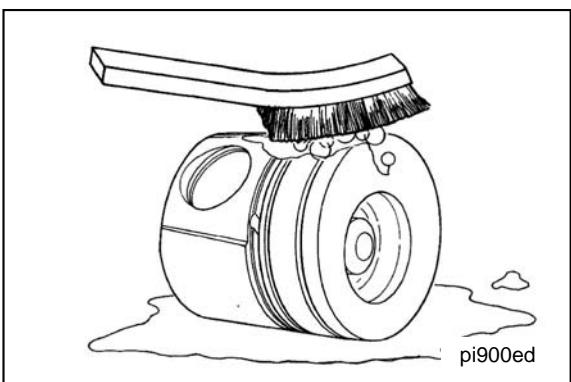
Do not use the bead-blast method to clean the piston. The piston can be damaged by blast material embedded in the aluminum.

⚠️ CAUTION

Do not clean the pistons in an acid tank. The piston can be damaged by the acid.

Soak the pistons in cold parts cleaner.

Soaking the pistons overnight will usually loosen the carbon deposits.

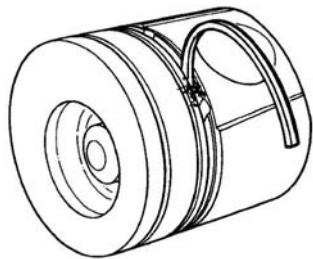


⚠️ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the pistons and rods in a strong solution of detergent in hot water.

Dry with compressed air.

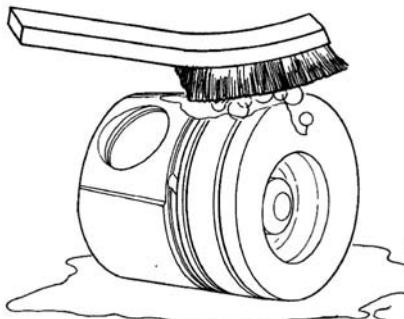


pi900ee

⚠ CAUTION

Do not use a ring groove cleaner and make sure not to scratch the ring sealing surface in the piston groove.

Clean the remaining deposits from the ring grooves with the square end of a broken ring.



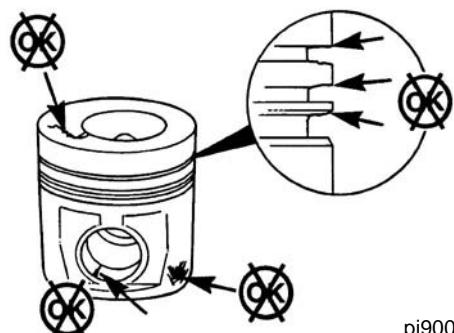
pi900ed

⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Wash the pistons again in a strong solution of detergent in hot water.

Dry with compressed air.



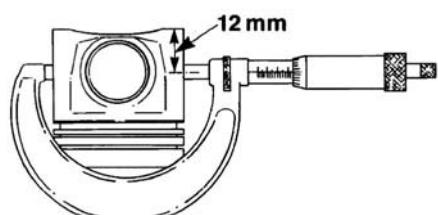
pi900sb



NOTE: If severe piston damage has occurred, check the turbocharger, cylinder head, and exhaust components for damage from debris.

Inspect the piston for damage and excessive wear.

Check the top, ring grooves, skirt, and pin bore.



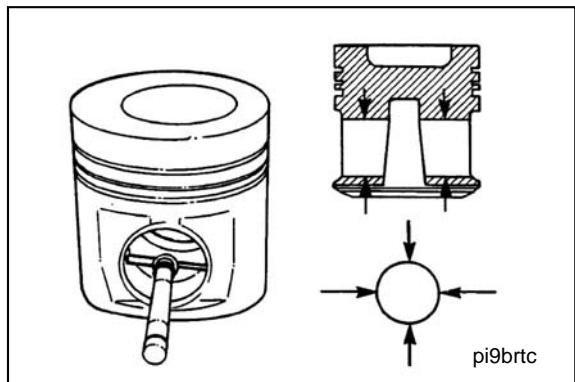
pi900tc



Measure the piston skirt diameter.

Piston Skirt Diameter

mm	in
94.85	MIN
95.00	MAX



Measure the pin bore.

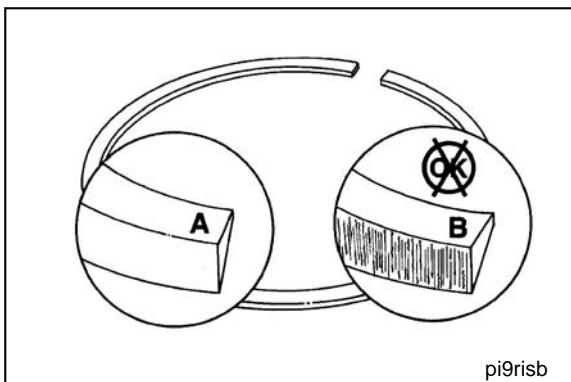


NOTE: Measure the pin bore in the center area of the bore. The bore profile is tapered on the edges and will result in a measurement error.

Piston Pin Bore Diameter

mm	in
30.00	1.181

Piston Rings



Inspect the piston rings for the following:

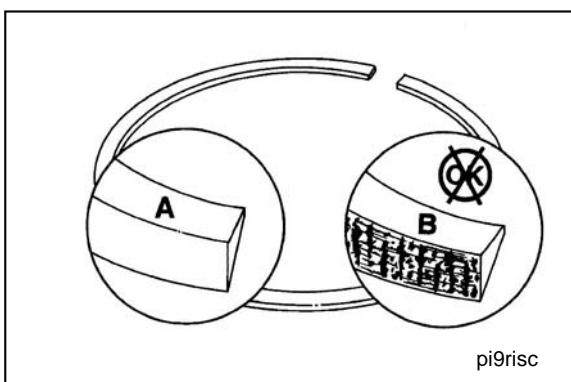


- Abrasive wear
- Scuffing and scoring
- Oil ring plugged with deposits.

Abrasive wear is indicated by concentrated vertical scratches (B). The chromium plating is worn through and the face of the ring has a brighter finish, when compared to the dull satin finish of a new ring (A).

Abrasive wear can be caused by:

- Ingested abrasive material
- Inadequate cleaning during a previous repair
- Particles embedded in the liner.
- Scuffing and scoring.



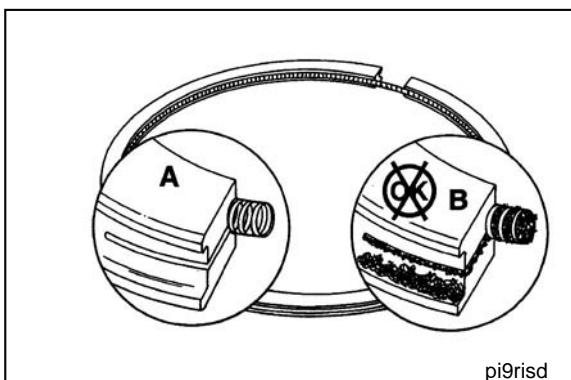
Scuffing and scoring is indicated by heavy scratches, metal discoloration, and voids (B).



Scuffing and scoring can be caused by:

- Engine overheating
- Oil dilution
- Improper maintenance of the lubrication system
- Piston cooling nozzle malfunction.
- Oil ring plugged by deposits.

Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder liner wall, causing transfer of material from the piston ring face to the cylinder liner.

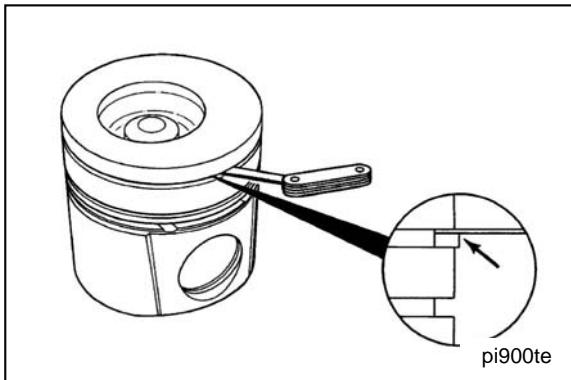


Oil ring plugging is indicated by deposits on the oil ring grooves (B).

Oil ring plugging can be caused by:

- Low engine operating temperatures - long periods of idling or a cooling system malfunction
- Extended oil change intervals
- Use of the wrong grade of engine oil
- Use of a poor-quality engine oil.

Plugging of the oil ring drains restricts oil drain back, which floods the piston ring belt area, resulting in a loss of oil control.



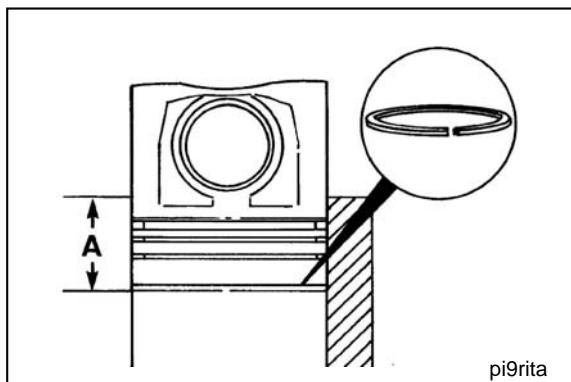
Width of Piston Groove

	mm	in
Top	2.0	0.079
Second	2.0	0.079
Oil Control	4.0	0.158

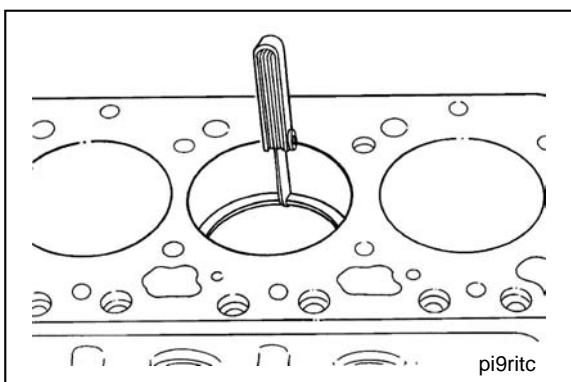
Use a new piston ring to measure the clearance in the ring groove.

Piston Ring Clearance

	mm	in
Top	0.06	0.0024
	0.10	0.0039
Second	0.03	0.0012
	0.07	0.0028
Oil Control	0.03	0.0012
	0.07	0.0028



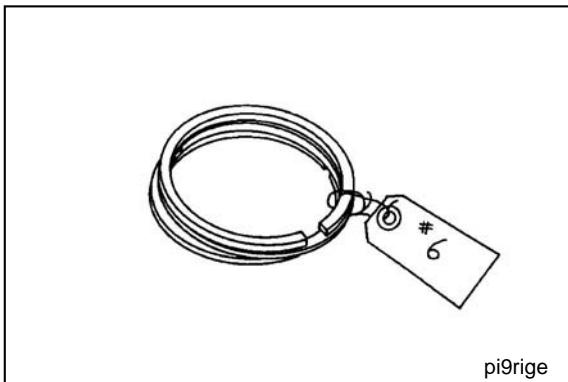
Position each ring in the cylinder below the ring reversal area, and use a piston to square it with the bore.



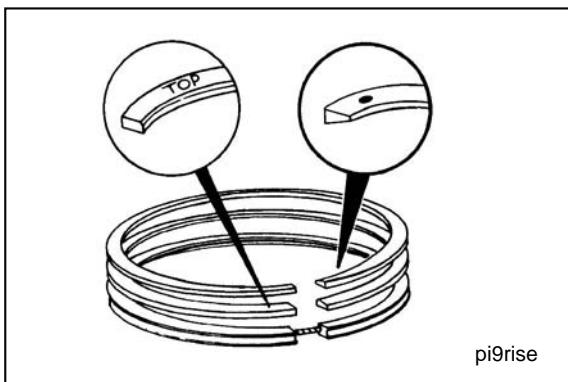
Use a feeler gauge to measure the piston ring gap.

Piston Ring Gap

	mm	in
Top	0.30	0.012
	0.45	0.018
Second	0.30	0.012
	0.45	0.018
Oil Control	0.25	0.0098
	0.45	0.018



Identify the ring sets for installation in the cylinder where the end gap was measured.

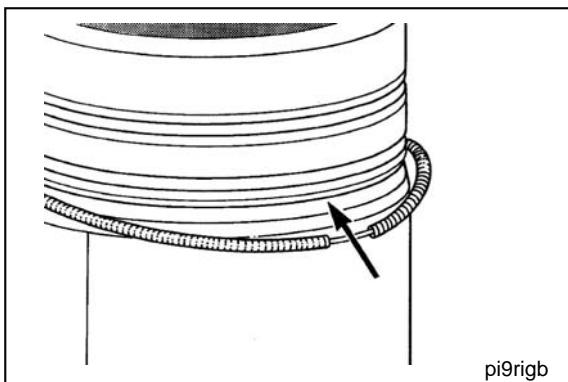


⚠ CAUTION

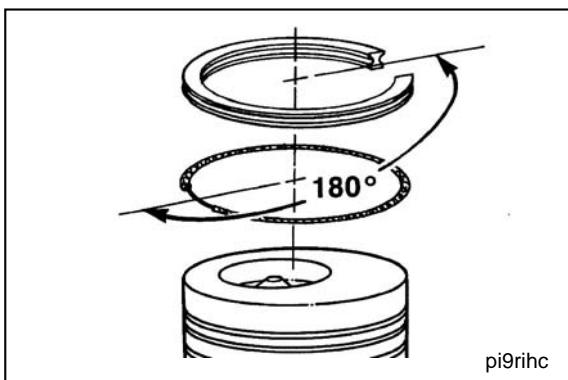
If a ring expander tool is being used, be careful not to over expand the ring.

The top surface of the top and intermediate rings are identified as illustrated.

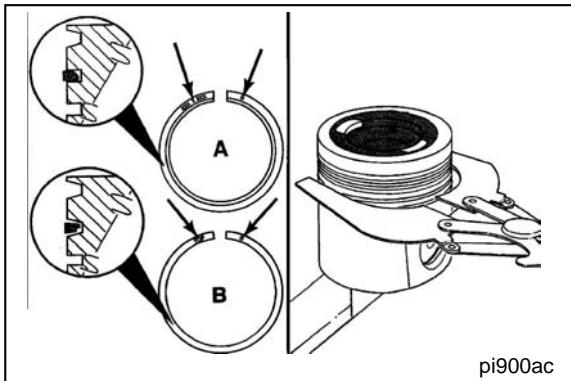
The oil control ring can be assembled with either side up.



Position the oil ring expander in the control ring groove.

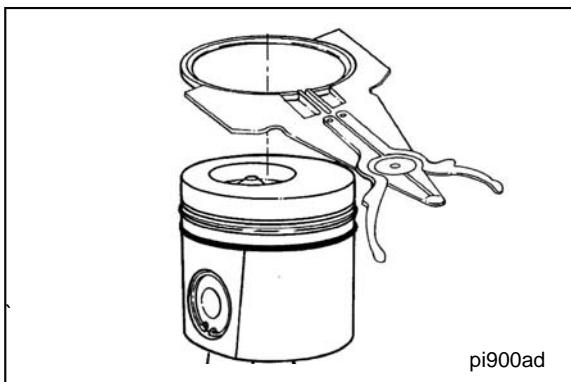


Install the oil control ring with the end gap 180 degrees from the ends of the expander.



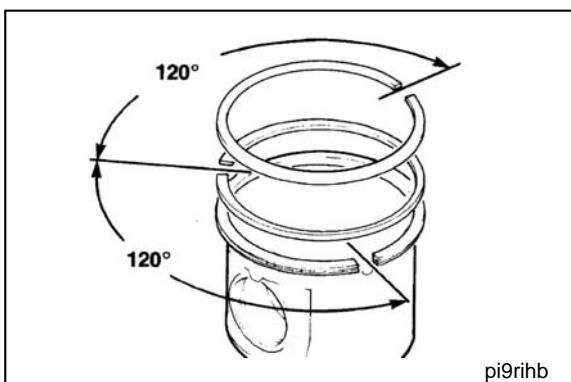
NOTE: Make certain that the dot and the word "TOP" are facing up when installing the piston rings.

Use piston ring expander, Part Number 3823137, or equivalent, to install the intermediate ring.



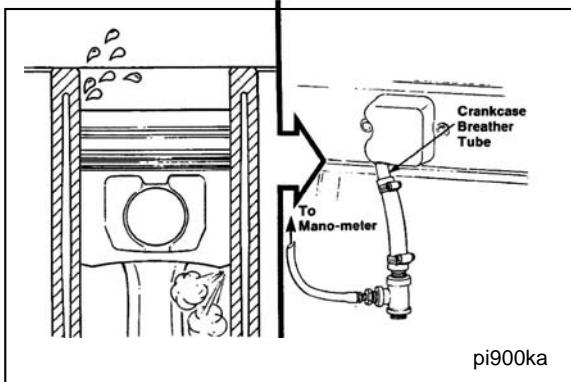
NOTE: The top ring has a shiny chrome appearance.

Use piston ring expander, Part Number 3823137, or equivalent, to install the top ring.

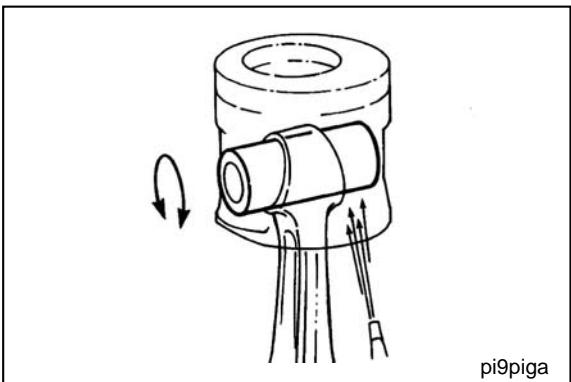


Position the rings so the ring gap are 120 degrees apart.

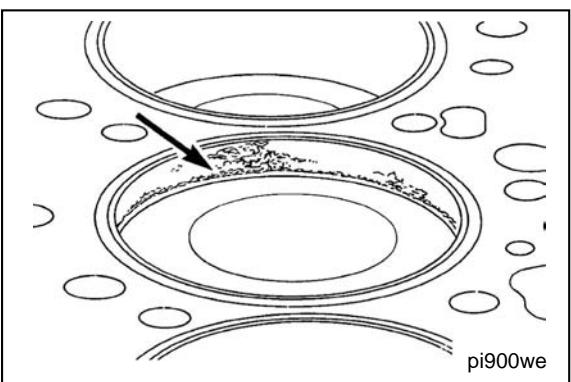
Piston and Connecting Rod Assembly



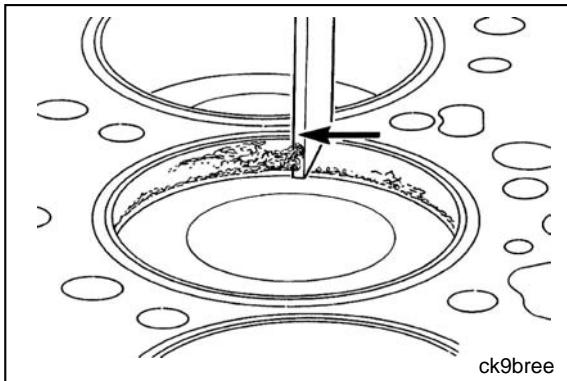
There are a number of power-related problems, including excessive lubricating oil consumption, smoke, blowby, and poor performance, that can be caused by inadequate sealing between the piston rings and the cylinder walls. A blowby measurement can help detect the problem. Refer to Procedure 014-010 for blowby measurement.



A free-floating, hollow piston pin is used to attach the piston to the connecting rod. Lubricating the pin and journal is accomplished by residual spray from piston cooling.



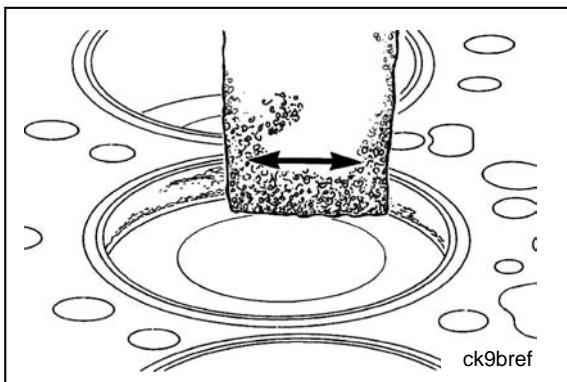
Rotate the crankshaft with an engine barring tool until the pistons are below the carbon deposits, which are found above the ring travel area.



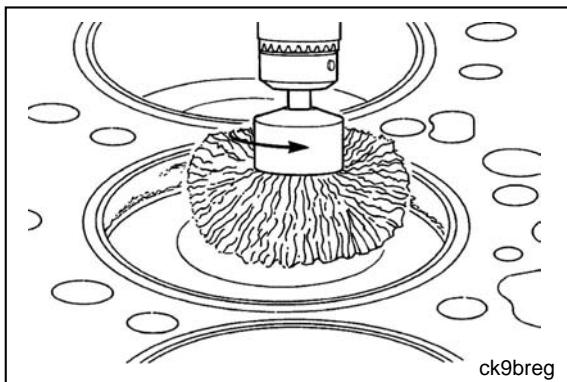
⚠ CAUTION

Do not use emery cloth or sandpaper to remove carbon from the cylinder bores. Aluminum oxide or silicon particles from these materials can cause serious engine damage.

Use a scraper or a blunt-edged instrument to loosen the carbon deposits. Do not damage the cylinder with the scraper.



Remove the remaining carbon deposits with an abrasive pad, Part Number 3823258, or equivalent.



⚠ WARNING

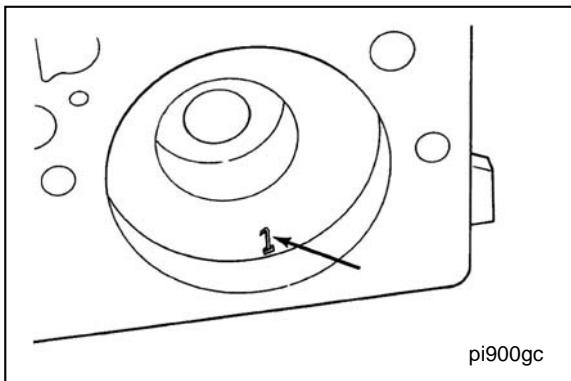
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

⚠ CAUTION

Do not use the steel wire wheel in the piston travel area. Operate the wheel in a circular motion to remove the deposits.

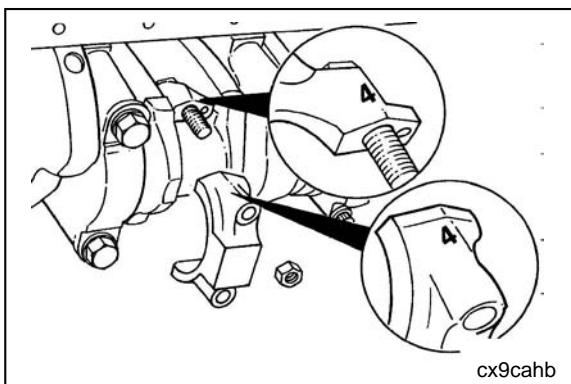
NOTE: An inferior quality wire wheel will lose steel bristles during operation, thus causing additional contamination.

An alternative method to remove the carbon ridge is to use a high-quality steel wire wheel installed in a drill or die grinder.



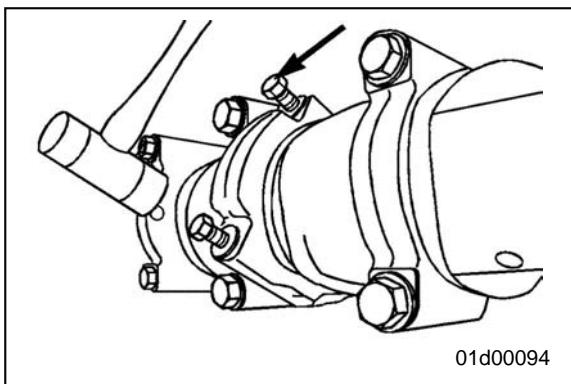
On pistons with anodized coatings, do not stamp the anodized coating on the outer rim.

Mark each piston according to the cylinder location.



Rotate the crankshaft to position the connecting rod caps at bottom dead center for removal.

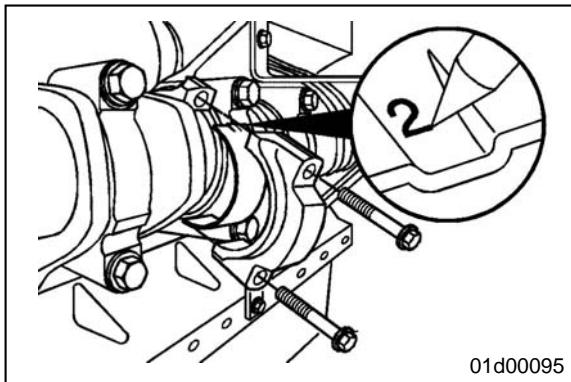
Mark each connecting rod and connecting rod cap according to the cylinder number location.



NOTE: Do not remove the capscrews from the connecting rods at this time.

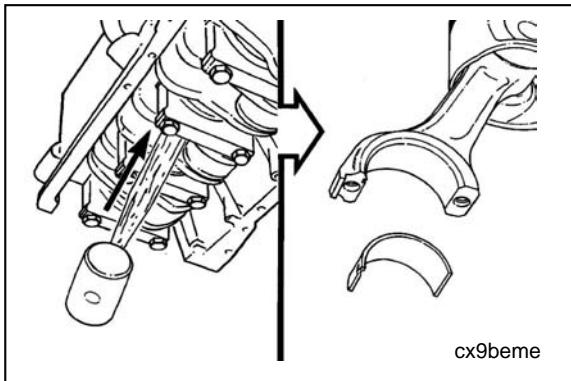
Loosen the connecting rod capscrews.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.



Remove the connecting rod capscrews.

Remove the connecting rod cap.

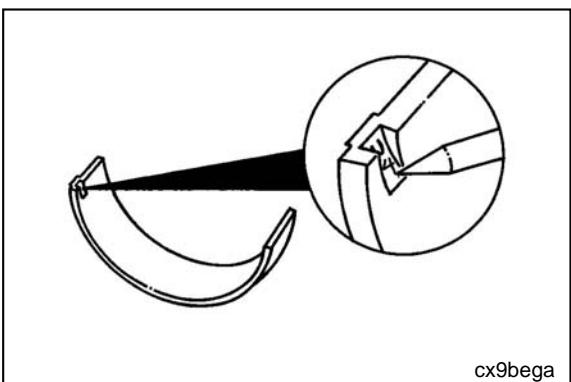


Remove the lower connecting rod bearing.

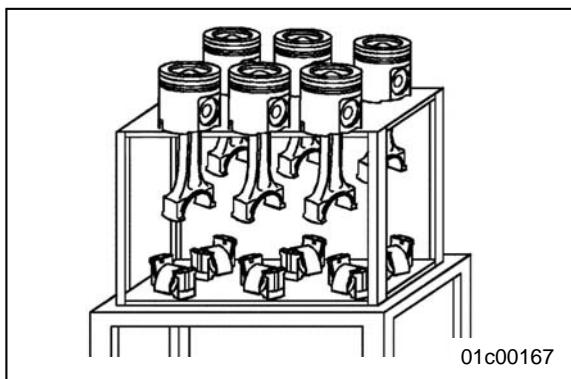
Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.

Push the connecting rod and piston assembly out of the cylinder bore. Care must be taken not to damage the connecting rod or bearing.

Remove the upper rod bearing.



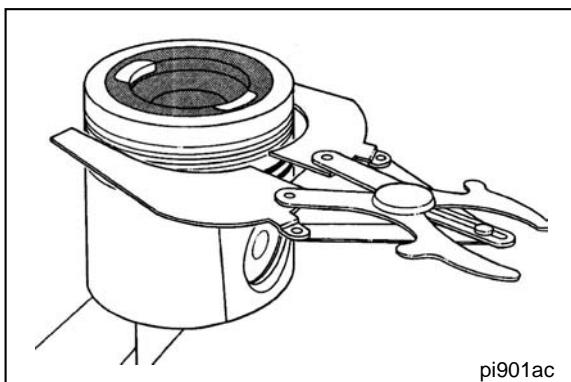
Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.



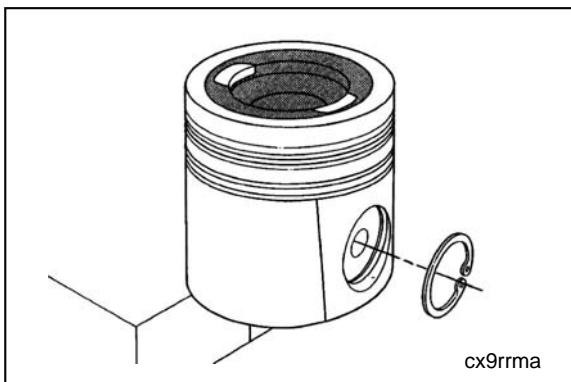
The piston and connecting rod assemblies must be installed in the same cylinder number from which they were removed, to provide proper fit of worn mating surfaces, if parts are reused.

Use a tag to mark the cylinder number from which each piston and rod assembly were removed.

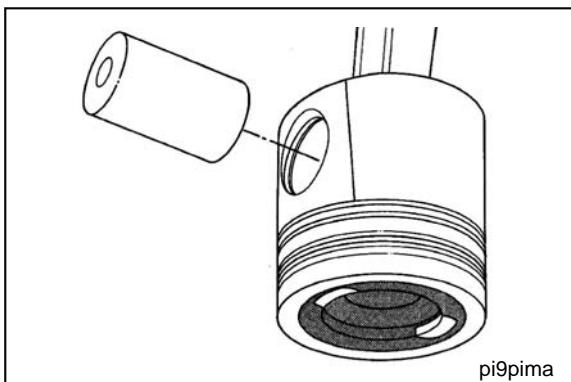
Place the rod and piston assemblies in a container to protect them from damage.



Use piston ring expander, Part Number 3823137, or equivalent to remove the piston rings.



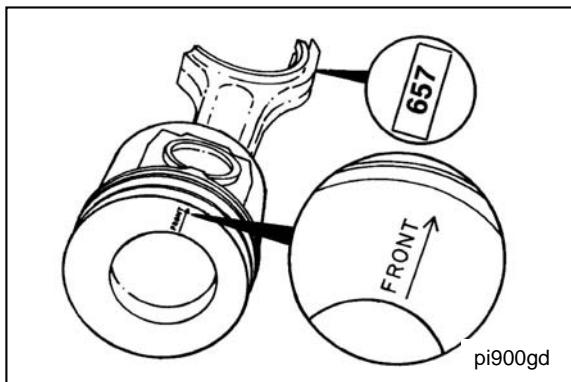
Remove the piston pin retaining rings.



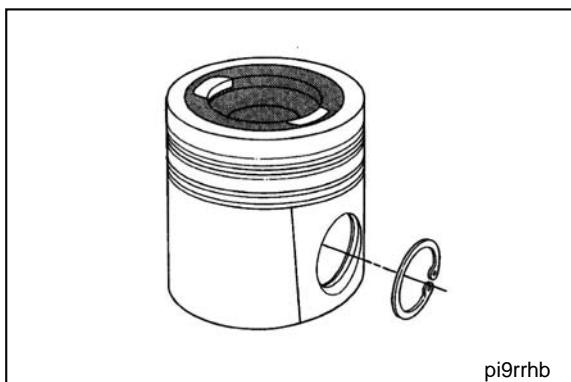
NOTE: Heating the piston is not required.

Remove the piston pin.

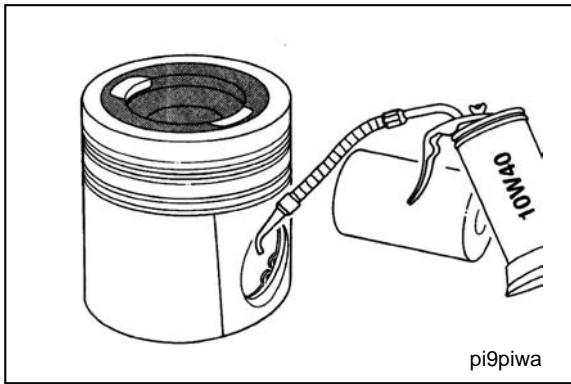
Remove the connecting rod from the piston.



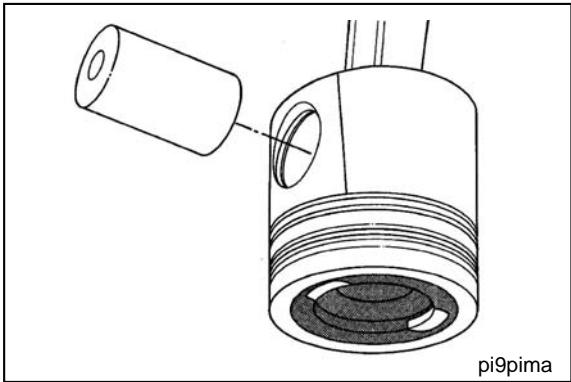
Make sure the FRONT marking on the piston and the numbers on the connecting rod and cap are oriented as illustrated.



Install the retaining ring in the pin groove on the front side of the piston.



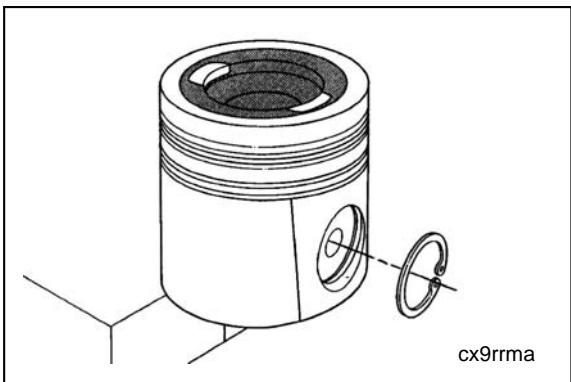
Lubricate the pin and pin bores with clean 15W-40 engine lubricating oil.



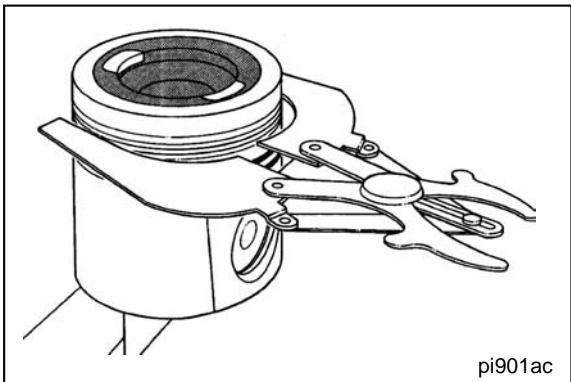
NOTE: Pistons do not require heating to install the pin; however, the pistons do need to be at room temperature or above.

Install the connecting rod.

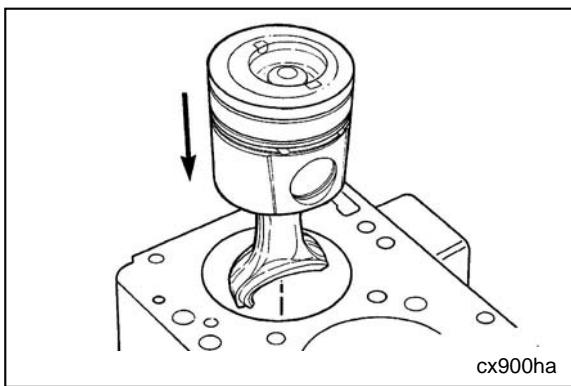
Install the piston pin.



Install the second retaining ring.



Use the piston ring expander, Part Number 3823137, or equivalent, to install the piston rings.

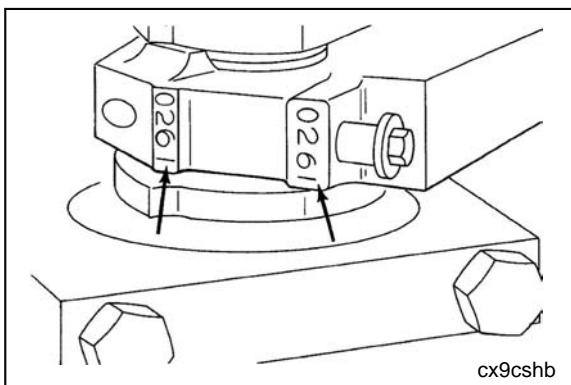


When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in their original cylinders.

If replacing the piston(s), make sure the replacement piston(s) are the same grade as the original piston(s).

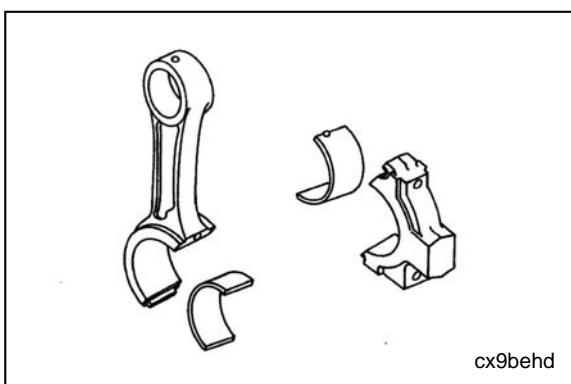
If a new cylinder block or crankshaft is used, the piston grading procedure must be performed to determine the proper piston grade for each cylinder.

Install the connecting rod and piston assembly into the Number 1 cylinder without the rings installed.



The number stamped on the connecting rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

Install the connecting rod cap and capscrews to the connecting rod.

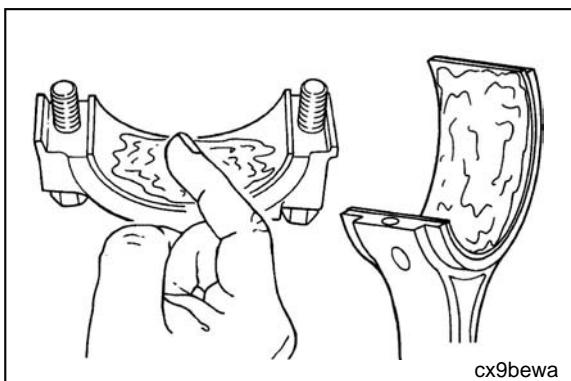


CAUTION

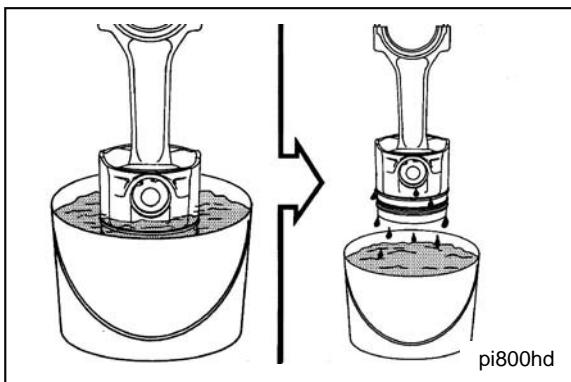
The connecting rods and connecting rod caps are not interchangeable. The connecting rods and connecting rod caps are machined as an assembly. Failure will result if the connecting rods and caps are mixed.

Install the bearing shells into both the connecting rod and the connecting rod cap.

Make sure the tang on the bearing shells is in the slot of the connecting rod cap and connecting rod.

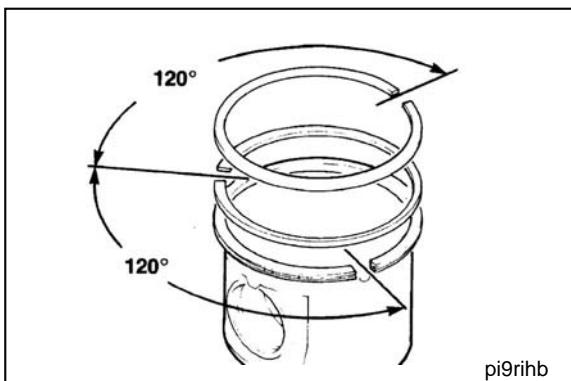


Lubricate the connecting rod bearings with clean lubricating engine oil.

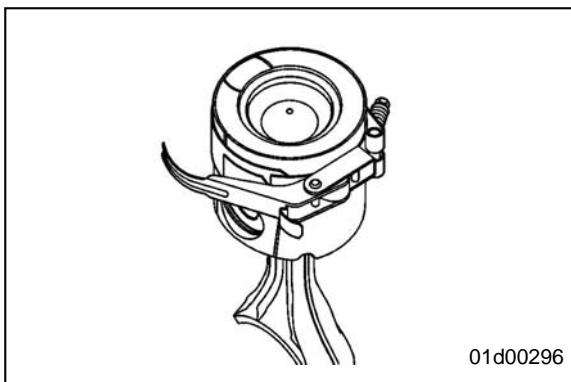


Immerse the pistons in clean 15W-40 engine lubricating oil until the rings are covered.

Allow the excess oil to drip off the assembly.



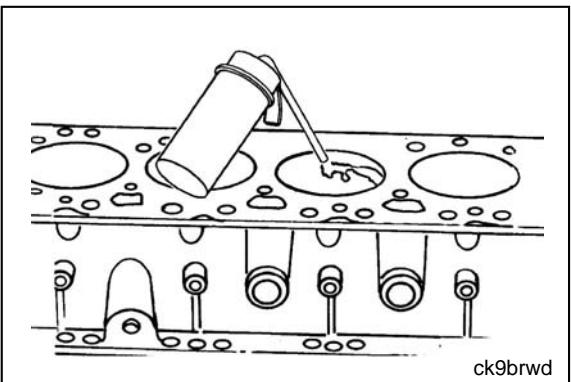
Position the rings so that the ring gaps are 120 degrees apart.



⚠ CAUTION

If using a strap type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.

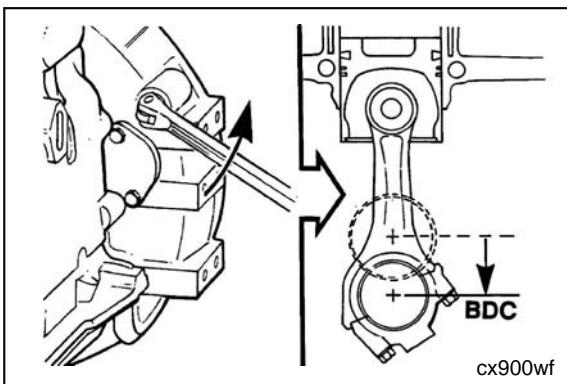
Use piston ring compressor, Part Number 3164330, or equivalent, to compress the rings.



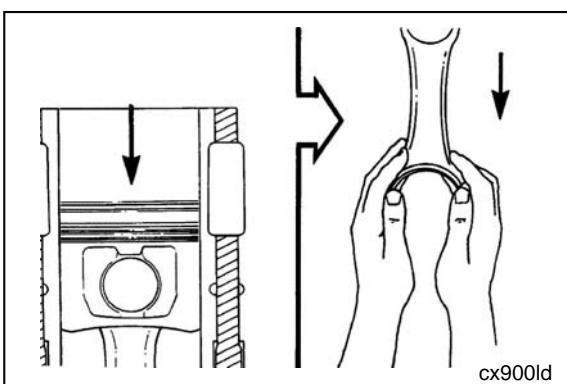
Lubricate the cylinder bore with clean 15W-40 engine lubricating oil.

The cylinder block must be clean before assembly.

Inspect the cylinder bores for reuse.

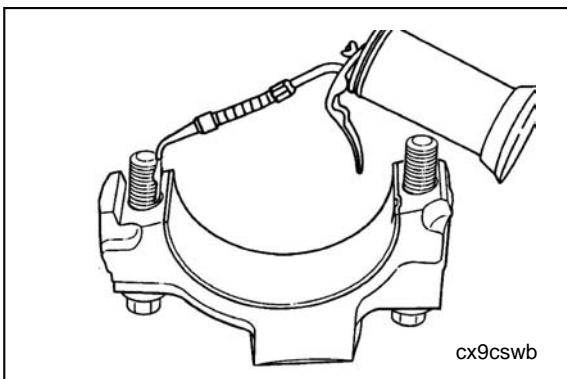


Position the connecting rod journal for the piston to be installed to bottom dead center (BDC).

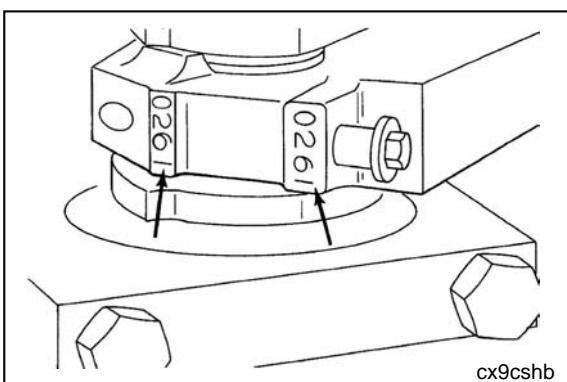


Take care to not damage the cylinder wall when inserting the connecting rod.

Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.



Lubricate the threads and underside of the connecting rod capscrew heads with clean 15W-40 lubricating engine oil.



CAUTION

The number stamped on the rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

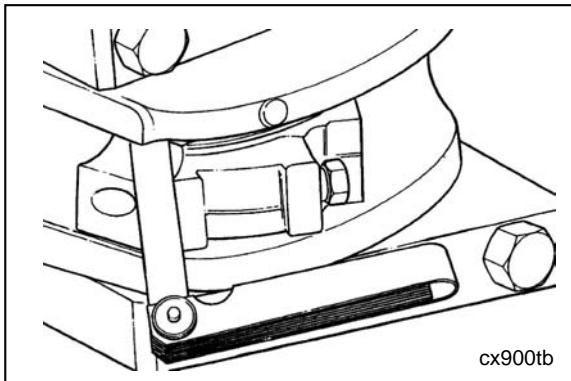
Install the connecting rod cap and capscrews.

Tighten the two capscrews in alternating sequence.

Torque Value:

Step1 39 n.m [29 ft-lb]

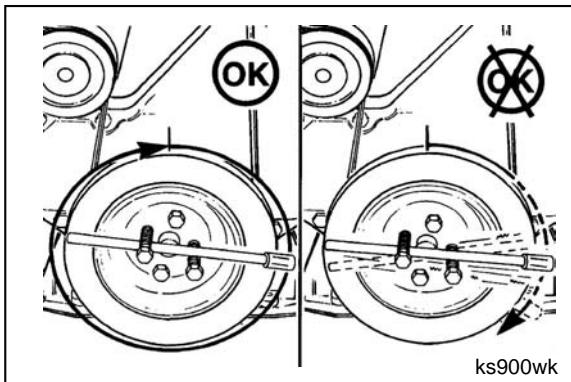
Step2 Rotate each capscrew 90 degrees.



NOTE: Do not measure the clearance between the connecting rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Connecting Rod Cap Side Clearance		
mm	in	
0.20	MIN	0.0079
0.40	MAX	0.0160



⚠ CAUTION

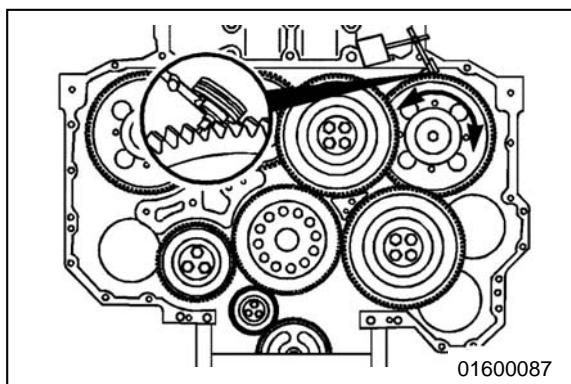
To reduce the possibility of engine damage, the crankshaft must rotate freely.

⚠ CAUTION

If the connecting rod is not properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.

Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does not rotate freely, check the installation of the connecting rod bearings and the bearing size.

Gear Train Backlash, Front

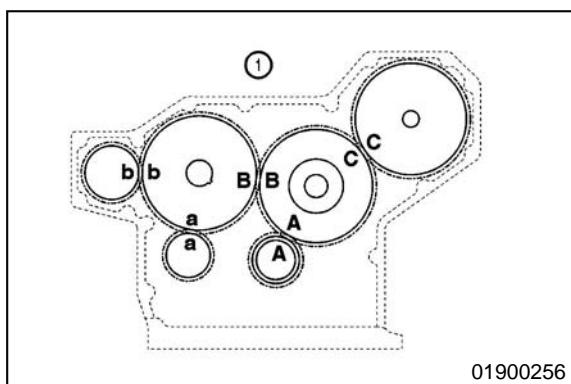


This check must be performed after the gear cover is removed or before installation.

The adjacent (engaging) gear must not turn as the gear being measured is turned.

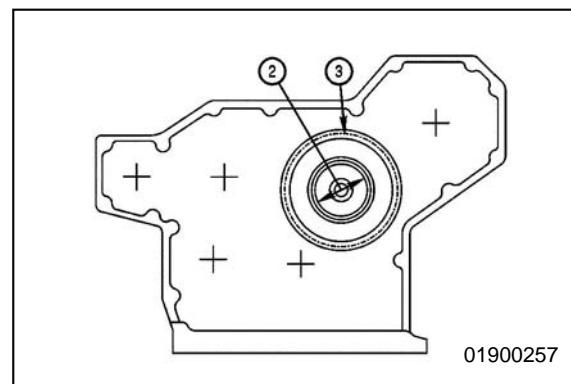
Position a dial indicator so the tip is contacting the surface of the gear tooth as shown. Do not allow the mating gear to turn.

Rotate the gear being measured clockwise. Position the indicator to zero (0). Rotate the gear counterclockwise and read the indicator.



Measure the gear backlash (1).

Timing Gear Backlash			
	Gear	Standard	Replacement Limit
A	Crankshaft gear and idler gear	0.08 to 0.19 mm [0.0031 to 0.007 in]	0.40 mm [0.0157 in]
B	Camshaft gear and idler gear	0.08 to 0.19 mm [0.0031 to 0.007 in]	
C	Injection pump gear and idler gear	0.07 to 0.29 mm [0.003 to 0.011 in]	
a	Camshaft gear and oil pump gear	0.07 to 0.29 mm [0.003 to 0.011 in]	
b	Camshaft gear and PTO gear	0.15 to 0.30 mm [0.006 to 0.012 in]	



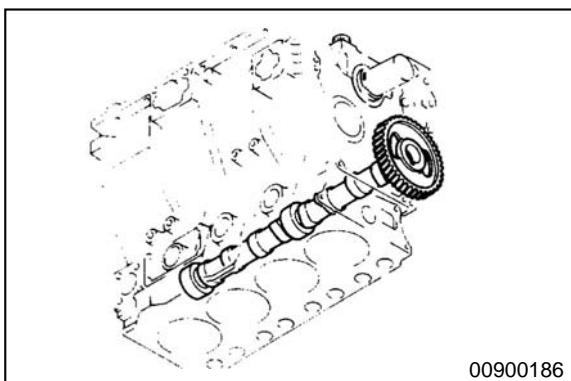
Measure the clearance between the idler gear bushing and shaft (2).

Clearance Between Idler Gear Bushing and Shaft	
Standard	Replacement Limit
0.015 to 0.050 mm [0.0006 to 0.002 in]	0.10 mm [0.0039 in]

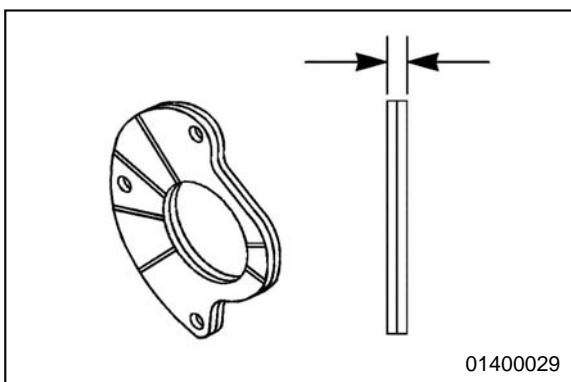
Measure the end play of the idler gear (3).

End Play of Idler Gear	
Standard	Replacement Limit
0.03 to 0.09 mm [0.0012 to 0.0035 in]	0.20 mm [0.0079 in]

Camshaft Thrust Bearing



Remove the thrust bearing.



CAUTION

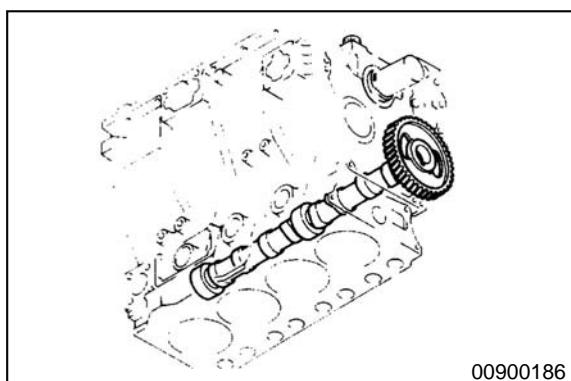
The bearings can separate during engine operation. Do not use room temperature vulcanized (RTV) sealant to hold the bearings together for assembly or the thickness can be too great when the room temperature vulcanized (RTV) sealant cures.

NOTE: The camshaft thrust bearing has two bearings. Both have a steel back with an aluminum overlay. The thrust bearing must be installed with the smooth sides against each other.

Inspect the thrust bearing for damage.

Measure the bearing thickness.

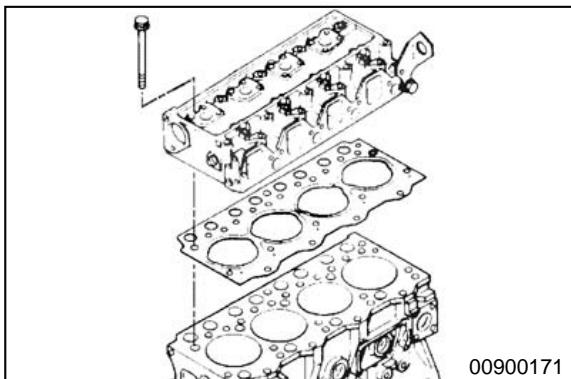
Camshaft Thrust Bearing Thickness		
mm	in	
0.150	MIN	0.0059
0.350	MAX	0.0138



Install the thrust bearing.



Cylinder Head

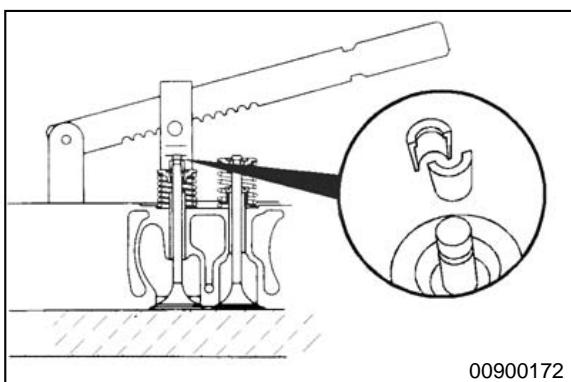


⚠️ WARNING

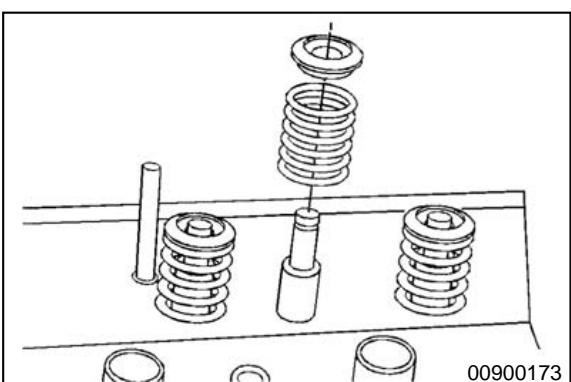
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

Remove the mounting capscrews, cylinder head assembly, and gasket.

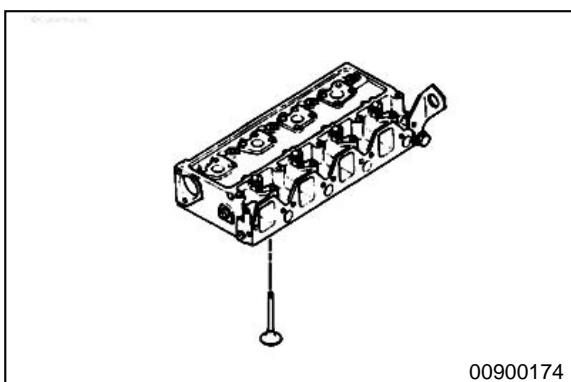
Discard the gasket.



Use a valve spring compressor, Part Number 3163292, or equivalent, to compress the valve spring(s), and remove the valve collets.

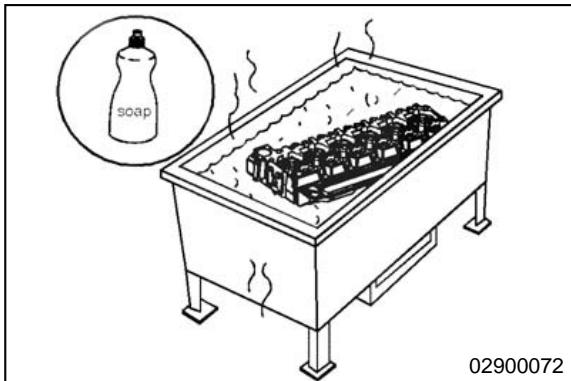


Loosen the spring, and remove the spring seat and valve spring.



NOTE: When removing the valve(s), mark them in the location where the valve was installed. This will aid in the assembly procedure.

Raise the cylinder head, and remove the valve.

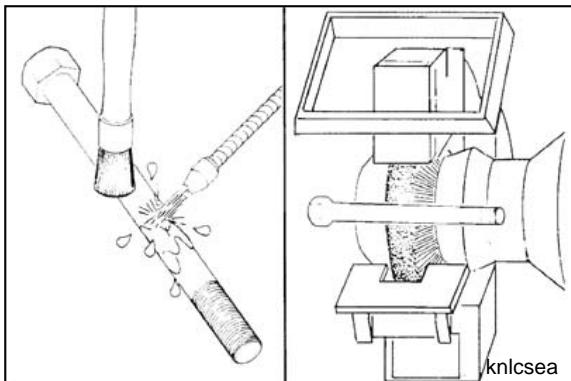


⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the cylinder head in hot, soapy water solution.

After rinsing, use compressed air to dry the cylinder head.



⚠ WARNING

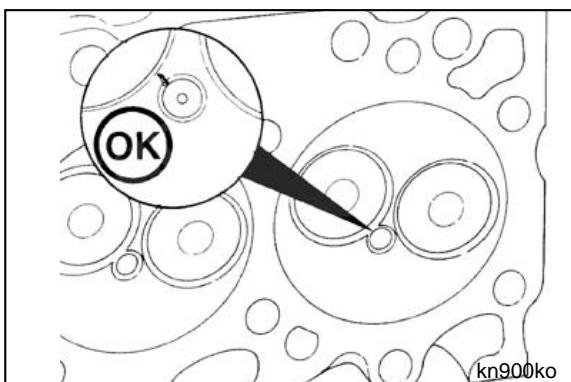
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ CAUTION

Do not use caustic or acidic solutions to clean the cylinder head capscrews. Use of this type of solvent can cause corrosion to the capscrews.

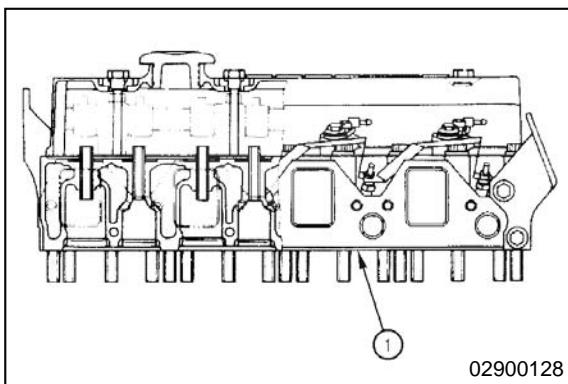
Use a petroleum-based solvent to clean the capscrews.

Clean the capscrew thoroughly with a wire brush or a soft wire wheel, or use a non-abrasive bead blast to remove deposits from the shank and the threads.



Inspect the cylinder head for cracks.

If a crack is found, and the crack does not extend into the valve seat the cylinder head can be used again.



Measure the cylinder head for surface flatness (1).

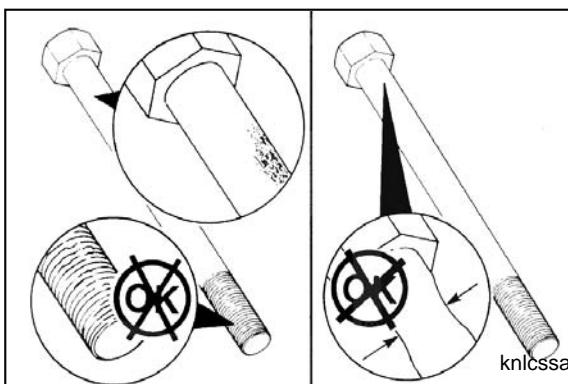


Cylinder Head Flatness(warping limit)

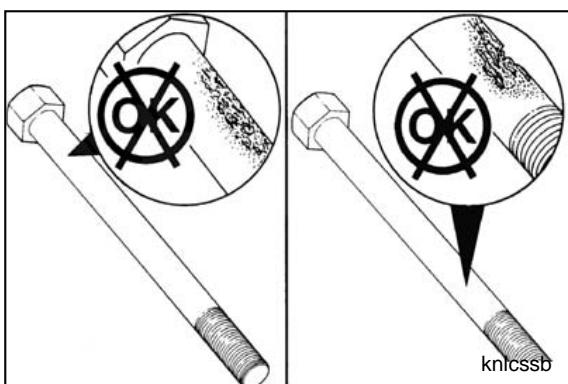
mm	in
----	----

0.00	MIN	0.00
0.05	MAX	0.002

The maximum repair limit on the cylinder head is 0.30 mm [0.012 in].

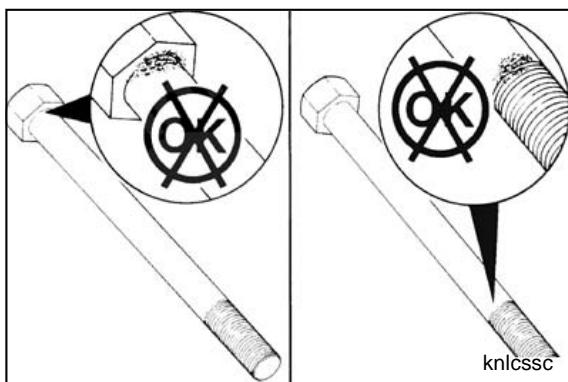


Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

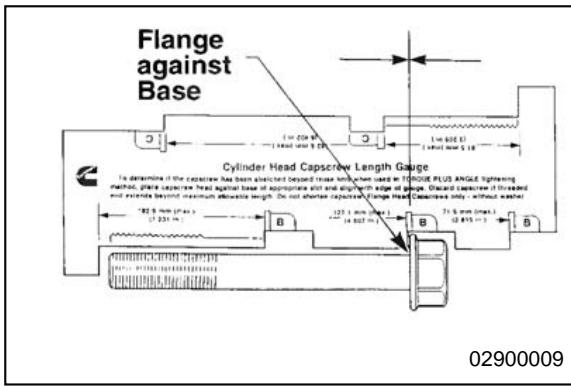


Do not use the cylinder head capscrews again under the following conditions:

- Corrosion or pitting that exceeds 1 sq. cm [0.155 sq. in] in area
- 10 mm [3/8 in] x 10 mm [3/8 in] is an acceptable area
- 13 mm [1/2 in] x 13 mm [1/2 in] is not an acceptable area
- Corrosion or pitting that exceeds 0.12 mm [0.005 in] in depth



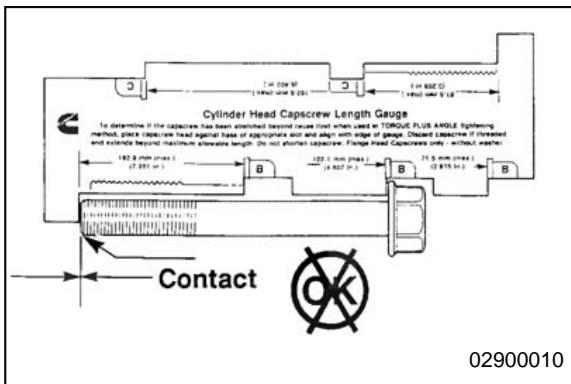
- Corrosion or pitting is located with 3.2 mm [1/8 in] of the fillet
- Corrosion or pitting is located within 3.2 mm [1/8 in] of the threads
- Stretched beyond "free length" maximum. Reference the following steps for capscrew lengths



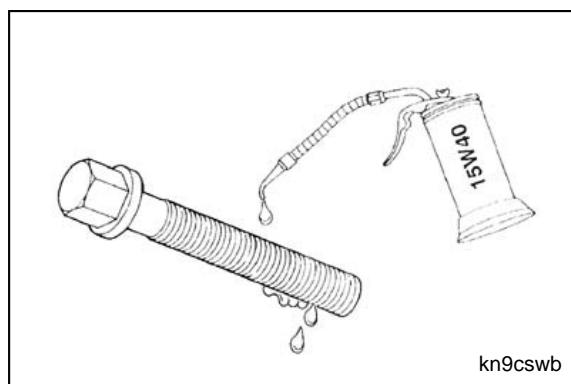
If the capcrews are not damaged, they can be used again throughout the life of the engine unless the specified "free length" is exceed.



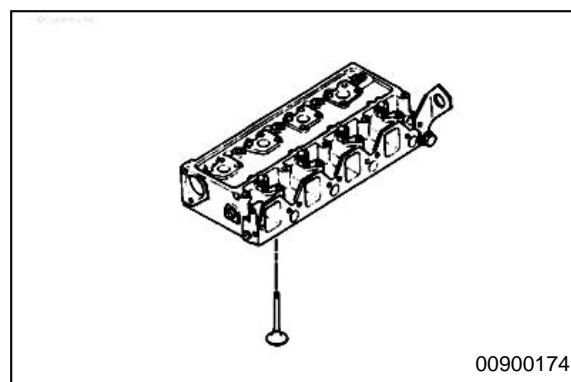
To check the capscrew "free length", place the head of the capscrew in the appropriate slot with the flange against the base of the slot. Refer to the manufacturer's specifications for the correct size of the cylinder head capscrews.



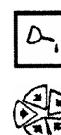
If the end of the capscrew touches the foot of the gauge, the capscrew is too long and must be discarded and replaced.

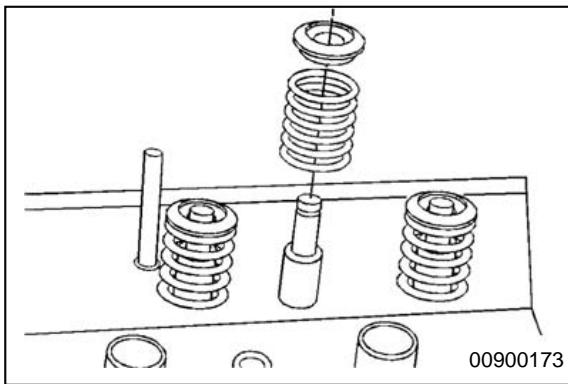


Immediately after cleaning and inspecting the capscrew. Apply a film of clean lubricating engine oil to all capscrews that are to be used again.

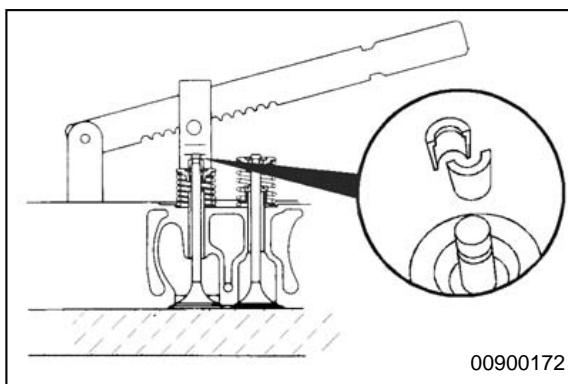


Coat the stems of the intake and exhaust valves and the inside of the valve guides with clean lubricating engine oil.

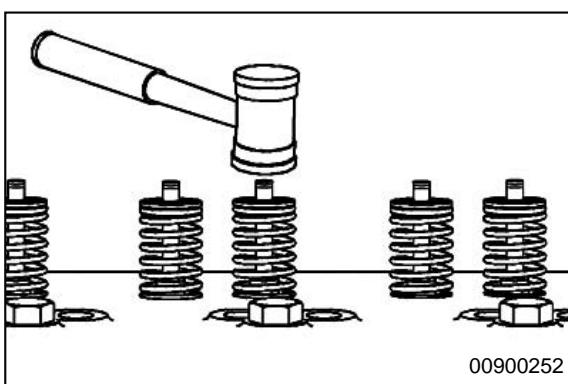




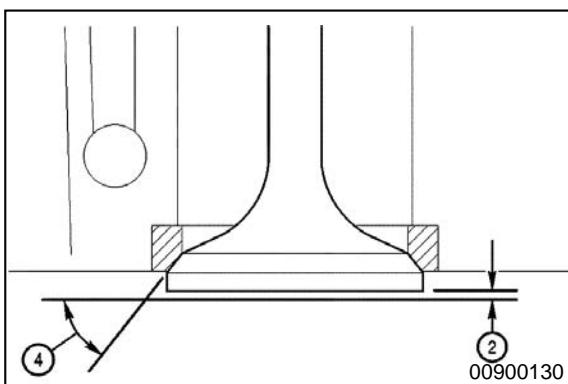
Install the valve spring and spring seat on the valve stem.



Install the valve collet onto the valve stem groove while compressing the valve spring with the valve spring compressor, Part Number 3163292, or equivalent.



After releasing the valve spring, tap the top of the valve stem with a plastic hammer to make sure the valve cotter is completely seated.



Measure the cylinder head valve seat recession (2).

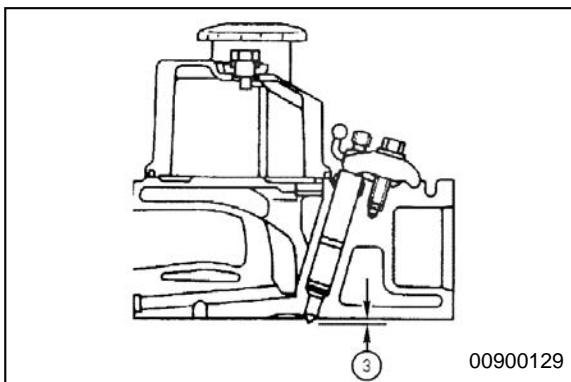
Valve Seat Specifications

	mm	in
Intake	1.00±0.100	NOM 0.039±0.004
Exhaust	0.90±0.100	NOM 0.035±0.004

Repair limit on the intake valve seat is 2.00 mm 0.079 in].

Repair limit on the exhaust valve seat is 1.90 mm 0.075 in].

Valve seat angle (4) is 45 degrees with a tolerance of $\pm 0^\circ 15'$. Repair limit condition is judged by vacuum test.

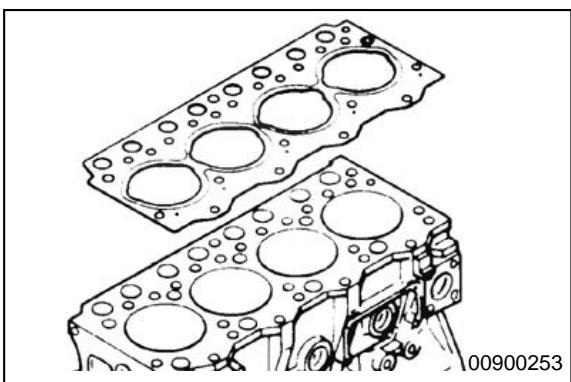


Measure the injector nozzle protrusion (3) on the cylinder head

Injector Nozzle Protrusion

mm	In
2.84	MIN 0.112
3.40	MAX 0.138

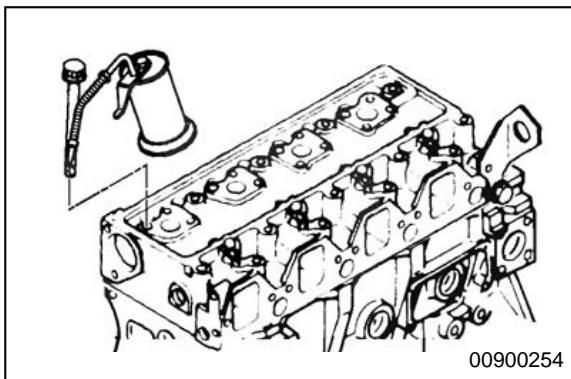
The tolerance allowance on the nozzle protrusion is 2.700 to 3.500 mm [0.106 to 0.138 in].



CAUTION

Remove all carbon and dirt from the contact surfaces of the cylinder block and cylinder head. Remove all burrs and debris from the cylinder block. Failure to do so can result in severe engine damage.

Install a new cylinder head gasket with the "TOP" mark facing up.

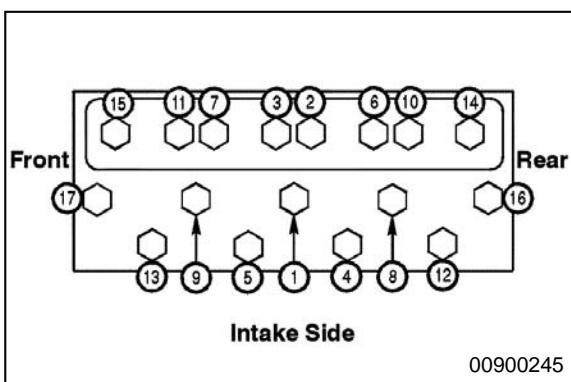


WARNING

This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

Coat the capscrew(s) threads with antiseize compound, Part Number 3824879, or equivalent.

Install the cylinder head using four head capscrews as guides.



The cylinder head capscrews can be used up to five times. Make a punch mark on the capscrew head each time the capscrew is used. If there are already five marks on the capscrew head, the capscrew must be replaced..

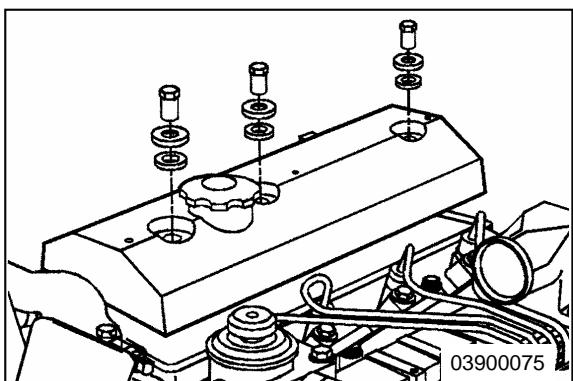
Install the capscrews. Tighten the capscrews in the sequence shown.

Torque Value:

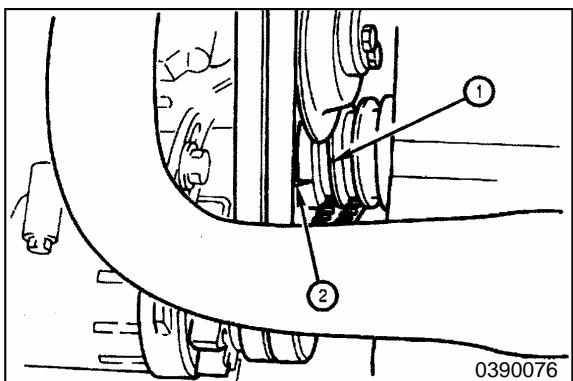
Step 1	69 n.m	[51 ft-lb]
Step 2	108 n.m	[80 ft-lb]
	Rotate 90 degrees	

Rocker Levers

Adjusting Valve Clearance



Remove the cylinder head cover.

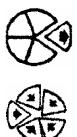
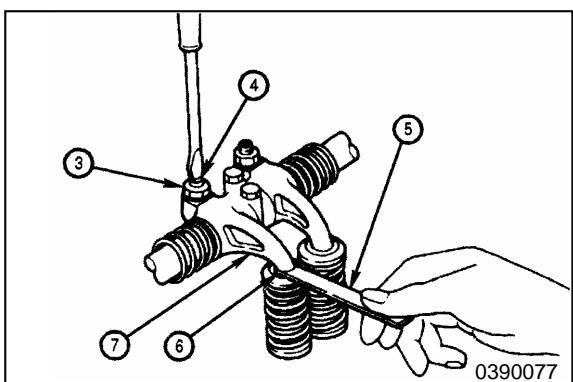


Rotate the crankshaft in the normal direction. While watching the movement of the intake valve of No. 4 cylinder, bring the No.1 cylinder into compression top dead center position. Align the TOP engraved mark on the crankshaft pulley (1) with pointer (2).



NOTE:

- The engraved mark on the crankshaft pulley will read "1.4 TOP."
- The No. 4 intake valve will start to open when the No. 1 cylinder comes near compression top dead center.

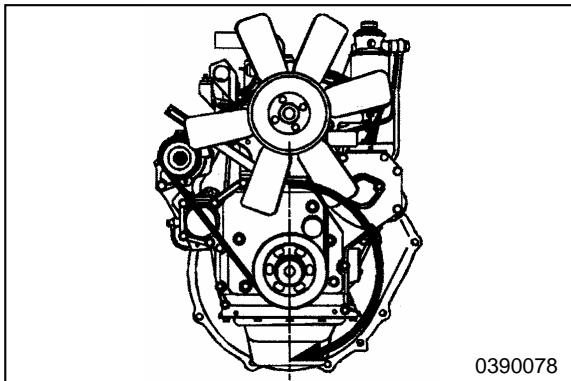


Loosen the lock nut (3) on the adjustment screw (4).

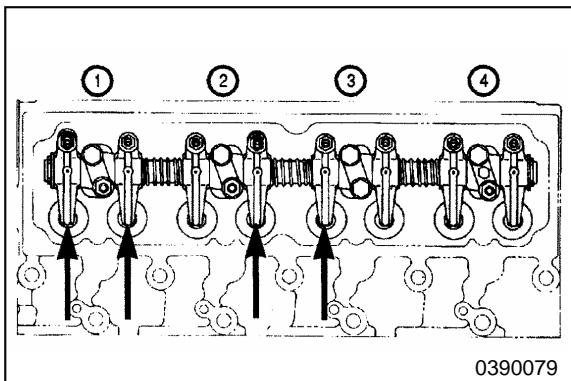
Insert the feeler gauge (5) between the valve stem (6) and the rocker arm (7).

Adjust the clearance with the adjustment screw until slight drag is felt on the feeler gauge.

Valve Clearance (Engine Hot or Cold)	
Intake Valve	Exhaust Valve
0.35 mm	0.50 mm
0.014 in	0.020 in

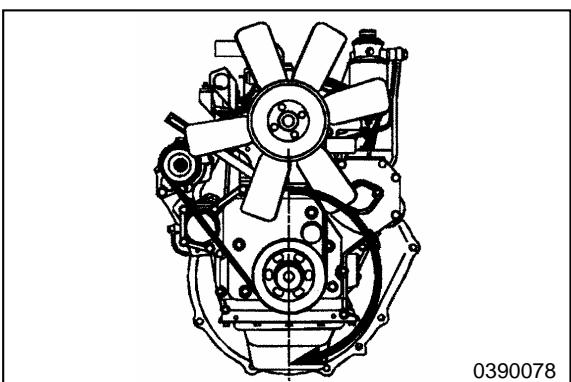


NOTE: Adjust intake and exhaust clearances in the following firing order by rotating the crankshaft 180 degrees in the normal direction: 1-2-4-3.



Adjust the valve clearances for **intake** valves No. 1 and No. 3.

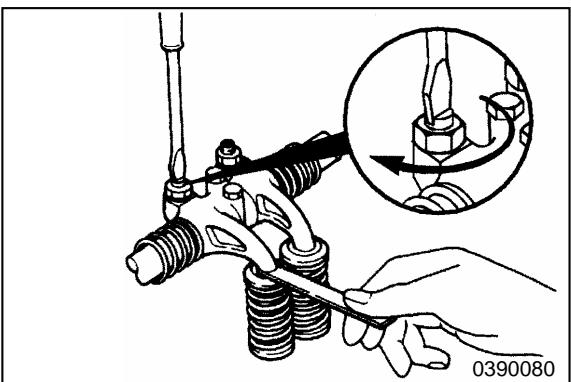
Adjust the valve clearances for **exhaust** valves No. 1 and No. 2.



Rotate the crankshaft in the normal direction one revolution.

Adjust the valve clearances for **intake** valves No. 2 and No. 4.

Adjust the valve clearances for **exhaust** valves No. 3 and No. 4.



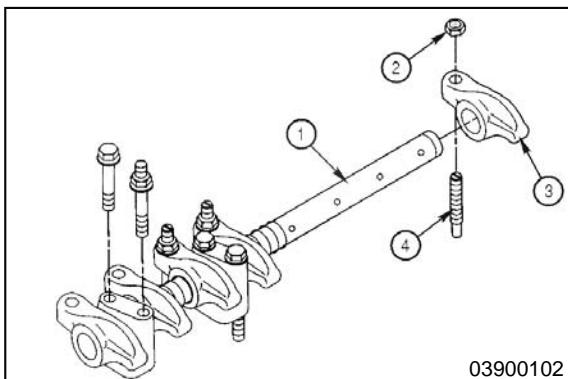
Tighten the locknut to secure the adjustment screw.



Locknut Torque Value

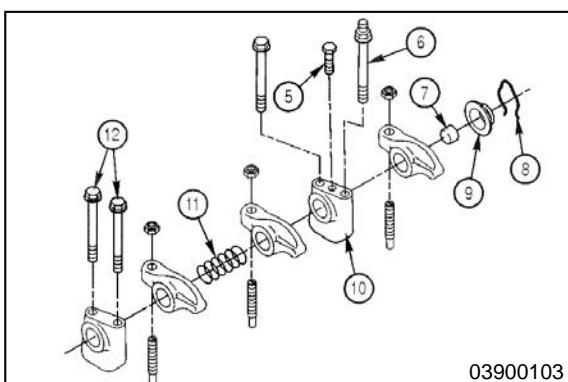
N·m	ft-lb
39.2	MIN
49	MAX

Rocker Levers Assembly

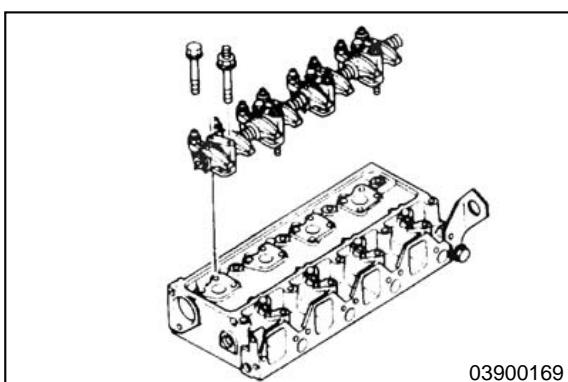


The rocker lever assembly contains the following components:

1. Rocker shaft
2. Adjusting screw locking nut
3. Rocker lever
4. Adjusting screw.

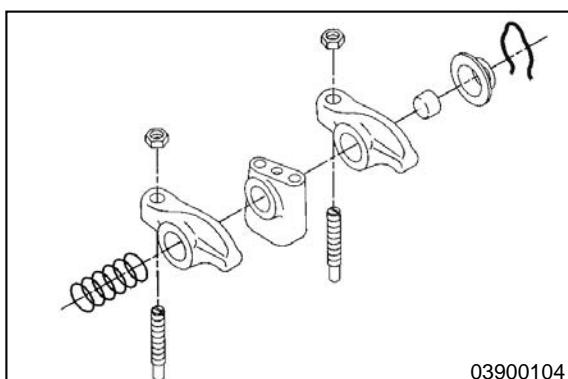


5. Rocker lever indexing screw
6. Pedestal mounting stud
7. Cup plug
8. Snap ring
9. Thrust washer (if equipped)
10. Rocker lever pedestal
11. Separating spring
12. Pedestal mounting capscrews.



NOTE: When removing the rocker arm, loosen the locknut, and turn the adjustment screw counterclockwise 2 to 3 turns.

Remove the mounting capscrews and the rocker lever assembly.

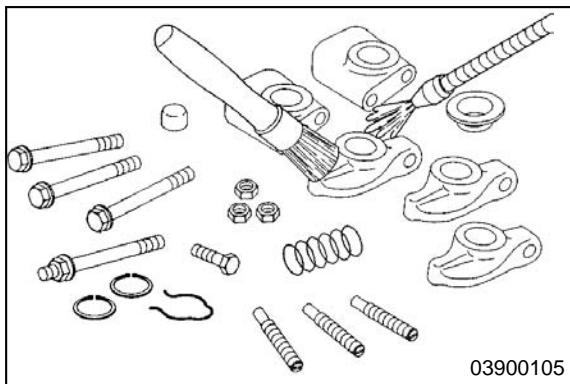


Remove the snap rings for each rocker lever.

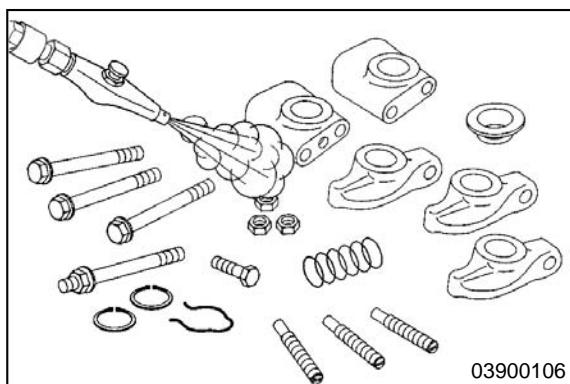
Remove the rocker lever shaft and thrust washers (if equipped).

Remove the rocker lever pedestals and rocker levers.

Remove the locknut and adjusting screw from rocker lever.



Clean all parts in a strong solution of detergent in hot water.



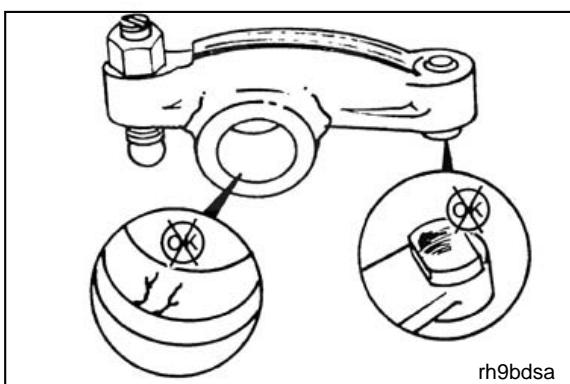
⚠ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

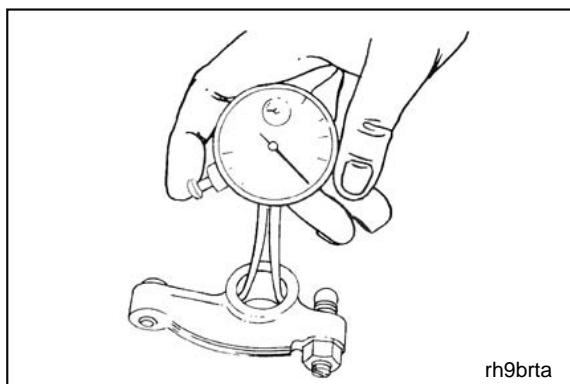
The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.

Rinse parts with clean hot water.

Dry parts with compressed air.

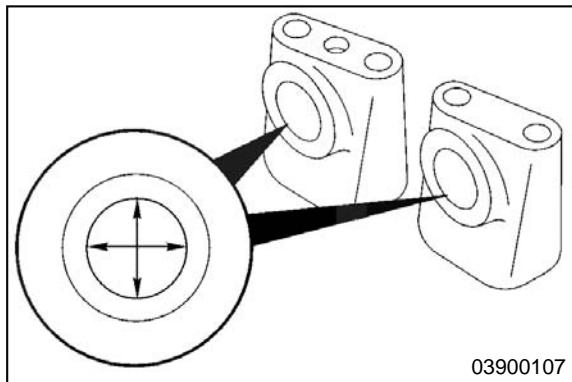


Inspect the rocker lever for cracks, excessive wear in the bore, and the contact surface of the valve stem.



Measure the rocker lever bore.

Rocker Lever Bore Diameter	
mm	in
19	0.75



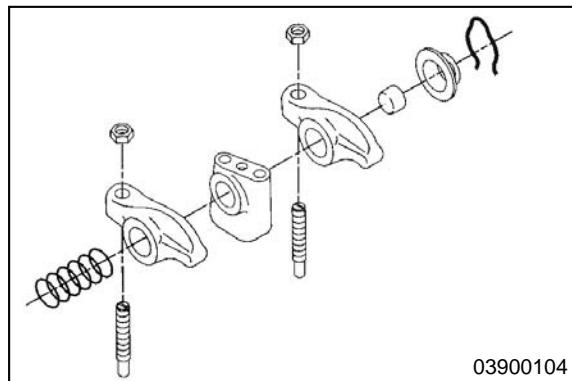
Inspect the pedestal and shaft bore.



Measure the pedestal shaft bore.

Rocker Lever Pedestal Bore

mm	in
19	NOM 0.75



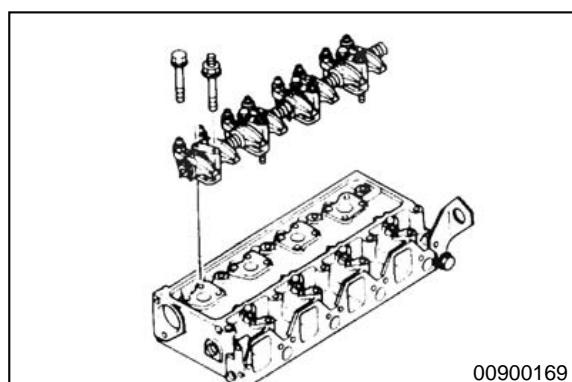
Install the locknut and adjusting screw in the rocker lever.



Install the rocker lever pedestals and rocker levers.

Install the rocker lever shaft and thrust washers (if equipped).

Install the snap rings for each rocker lever.



NOTE: Check that the ball of the adjustment screw is fitted properly into the socket of the pushrod before tightening the capscrews. If the valve spring tension pushes against the rocker arm, loosen the locknut, and turn the adjustment screw back to prevent strain on the pushrod.



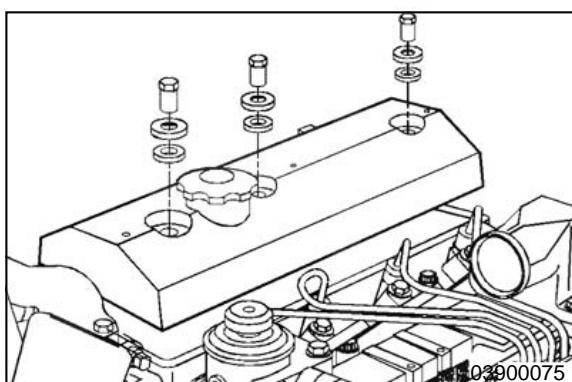
NOTE: Tighten the middle pedestal capscrew first.

Install the rocker lever assembly and mounting capscrews.

Tighten the capscrews.

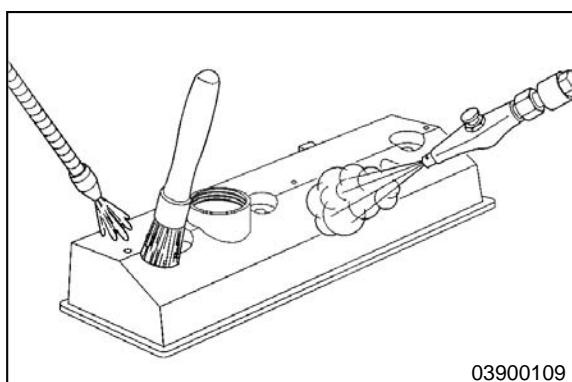
Torque Value: 25 n.m [18 ft-lb]

Rocker Lever Cover



Remove the three capscrews, isolator assemblies, o-rings, and rocker lever cover.

Remove the gasket. Discard the gasket.

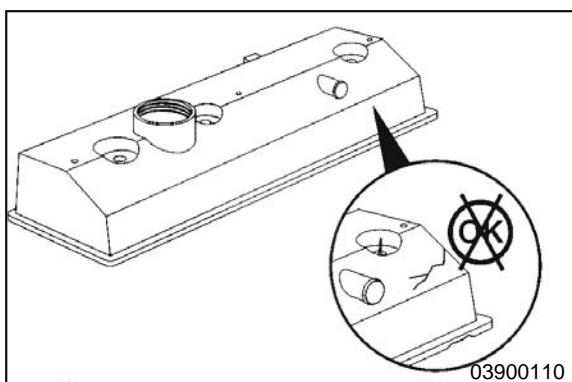


WARNING

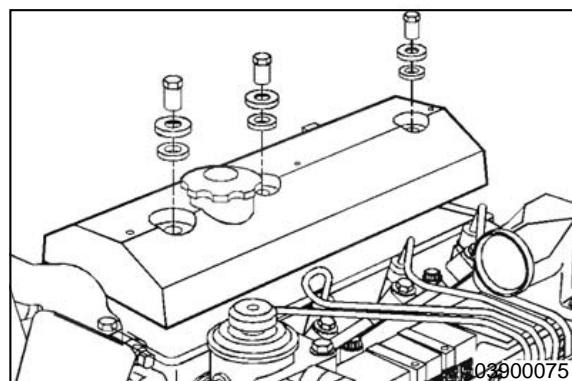
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the rocker lever cover with a strong solution of detergent in hot water.

Dry the rocker lever cover with compressed air.



Inspect the rocker lever cover for cracks and other damage.



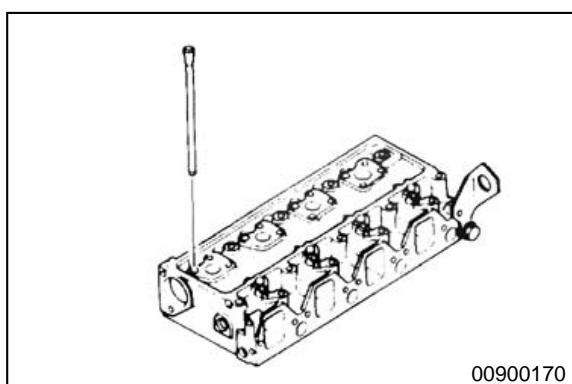
Install the new gasket.

Install the rocker lever cover, o-rings, isolator assemblies, and three capscrews.

Tighten the capscrews.

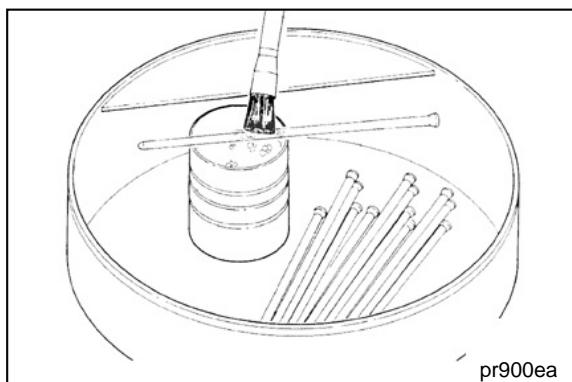
Torque Value: 9 n.m [80 in-lb]

Push Rods or Tubes



NOTE: Mark the push rods with tags showing the location. Keep the push rods from getting damaged. Install the push rod in the same location during assembly.

Remove the push rods from the cylinder head.

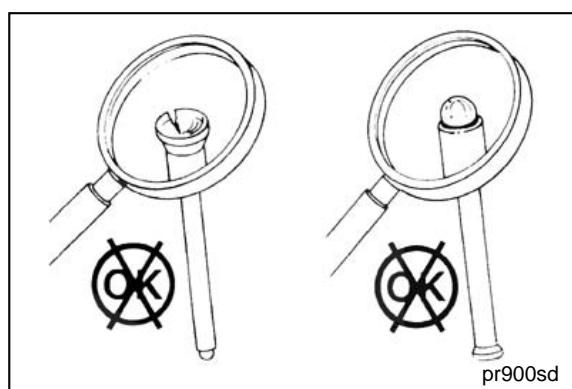


WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

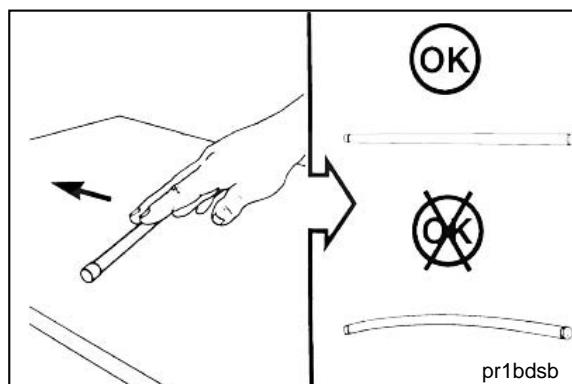
Clean the push rods in a strong solution of detergent in hot water.

Dry with compressed air.



Inspect the push rod ball and socket for signs of scoring.

Check for cracks where the ball and the socket are pressed into the tube.



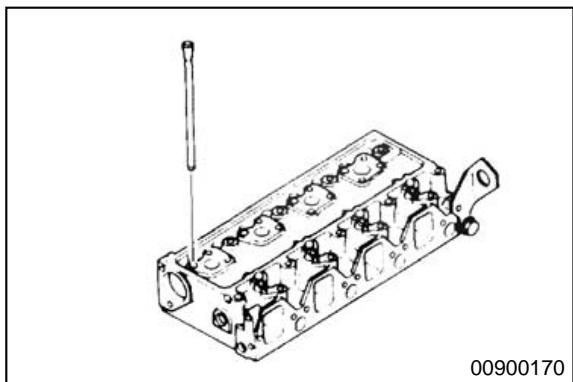
NOTE: When a push rod is replaced, the corresponding tappet must be replaced also.

Check the push rods for roundness and straightness.

Use a round feeler gauge on a flat surface.

Straightness or Bend of push Rod

mm	in
0.30	MAX

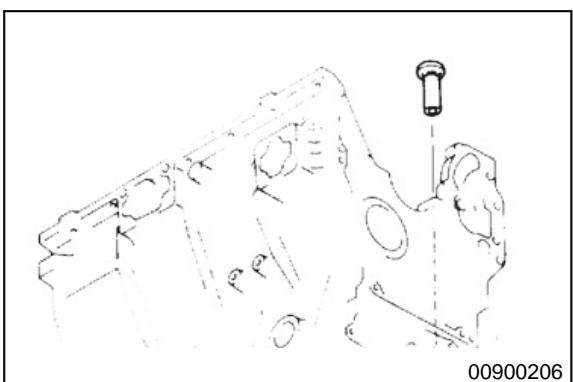


Lubricate the push rod ends with clean lubricating engine oil.



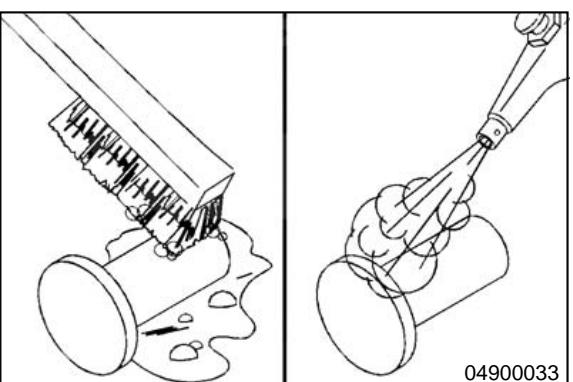
Install the push rods into the cylinder head in the location as marked.

Tappet



NOTE: Mark the location of the tappets if tappets are to be used again.

Remove the tappets.

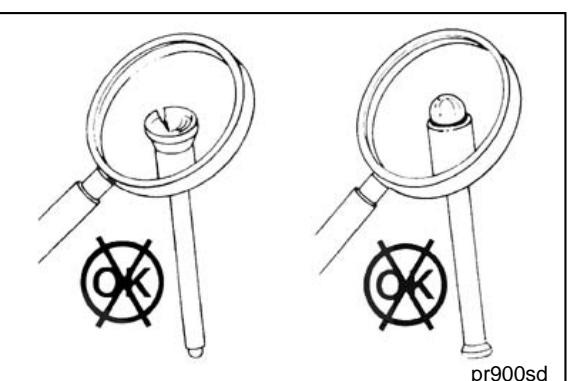


WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the tappets with a strong solution of detergent in hot water.

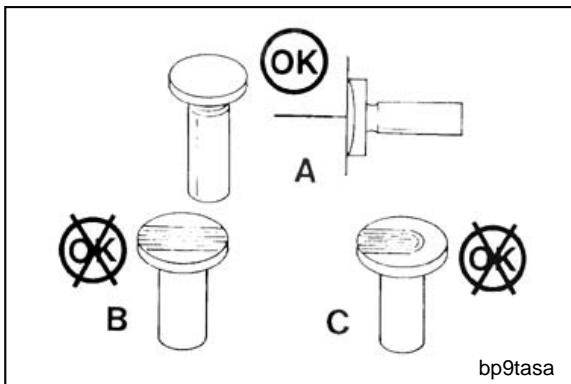
Dry the tappets with compressed air.



When a new camshaft is installed, new tappets and push tubes must also be installed.



When the tappets need to be replaced, the corresponding push tubes must also be replaced.

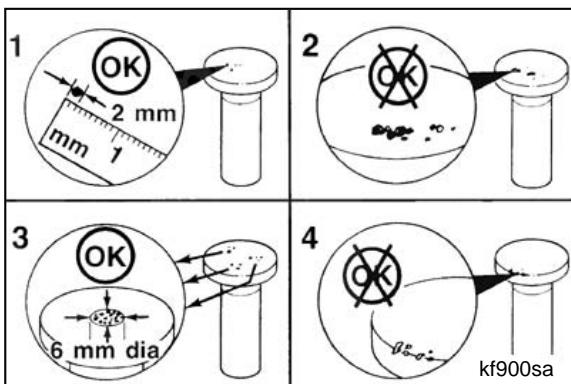


Inspect the face of the tappet for excessive wear, cracks, and other damage.

Visual Limits

(A) - Normal contact (exaggerated)

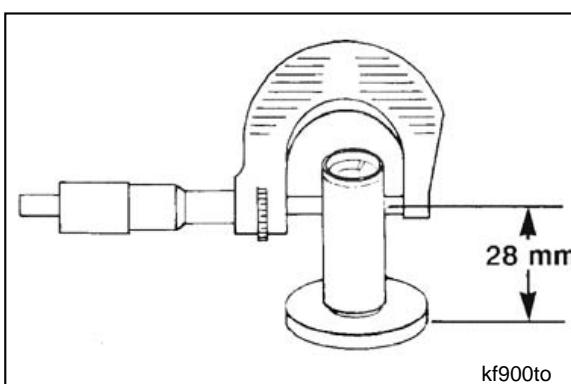
(B) and (C) - Irregular contact (do not reuse).



Pit marks on the tappet face are acceptable.

The following criteria defines the size of the pits allowed:

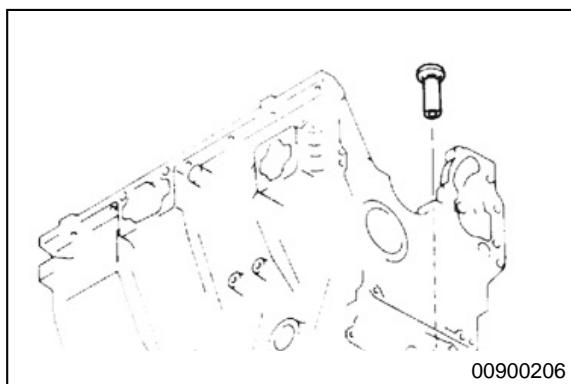
1. A single pit can not be greater than 2 mm [0.078 in].
2. Interconnection of pits is not allowed.
3. Total pits when added together must not exceed 6-mm [0.236-in] in diameter or total of 4 percent of the tappet face.
4. No pitting is allowed on the edges of the wear face of the tappet.



Measure the valve stem diameter 28 mm [1.1 in] from the face of the tappet.

Valve Tappet Stem Diameter

mm	in
16	0.63



Lubricate the tappets with clean lubricating engine oil.

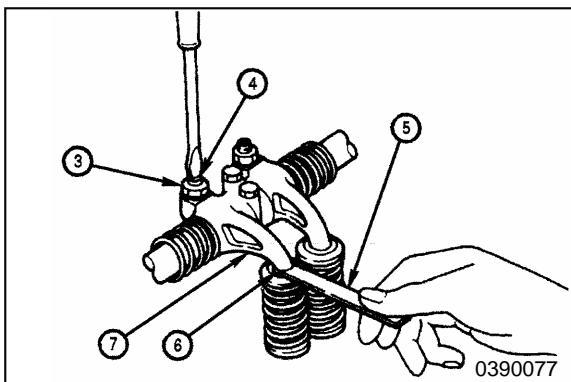
Install the tappets.

Complete Engine

Measuring Compression Pressure

⚠ WARNING

Exhaust manifold and muffler are hot. Do not touch the exhaust manifold or muffler or personal injury will occur.

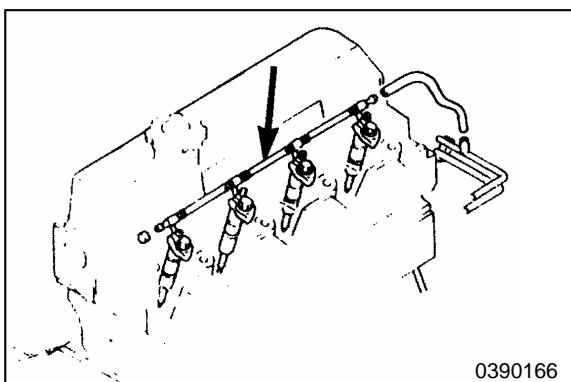


⚠ WARNING

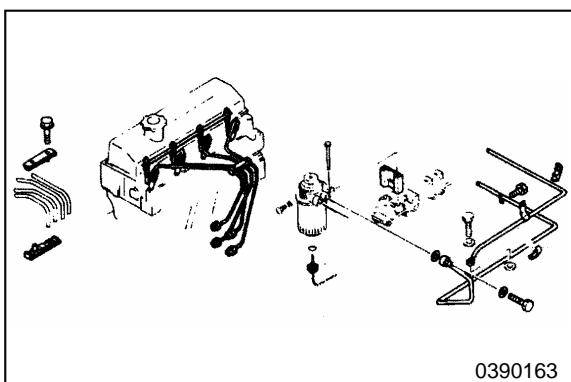
To avoid personal injury, keep hands, long hair, jewelry, and loose fitting or torn clothing away from fans and other moving parts.



Adjust the overhead. Refer to Adjusting Valve Clearance procedure.

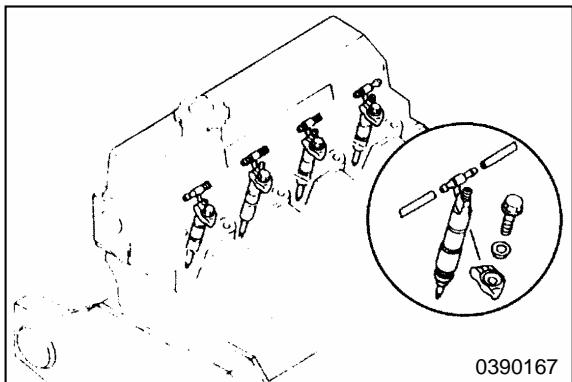


Remove the spill tube.



Disconnect the fuel injection tubing.

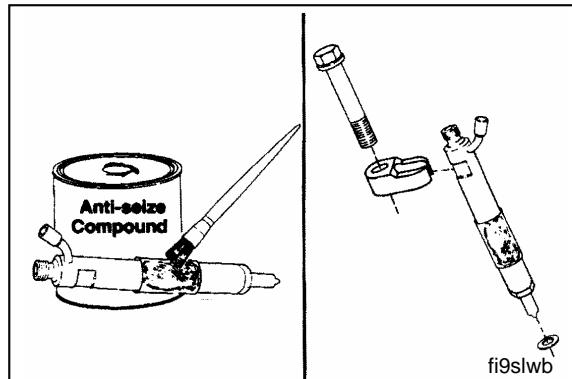
NOTE: Disconnect the fuel shut-off solenoid.



CAUTION

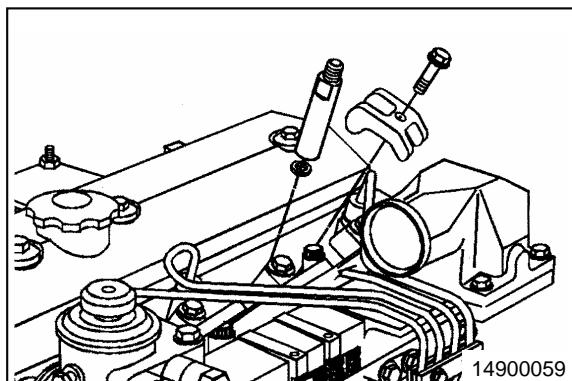
Do not allow dirt or foreign matter to get into the cylinder. Foreign objects in the cylinder can cause severe engine damage.

Remove the nozzle holder assembly for each cylinder. Remove the injector.



Lubricate the sealing lips of the sleeve with anti-seize compound. Assemble the injector, sealing sleeve, a new copper sealing washer, and the hold-down clamp. **Use only one washer.**

NOTE: A light coat of clean 15W-40 engine oil between the washer and injector can help hold the washer in place during installation.

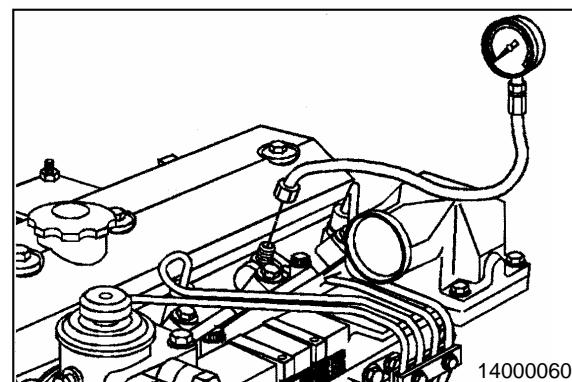


Install the adapter to the nozzle holder mounting section of the cylinder to be measured. Tighten the adapter.



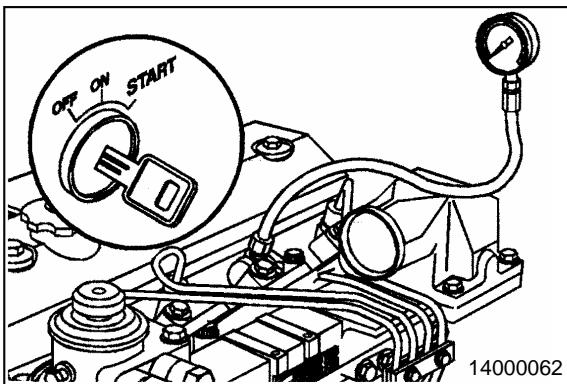
Adapter Capscrews

N·m	ft-lb
39	MIN
49	MAX



Connect the compression gauge to the adapter.

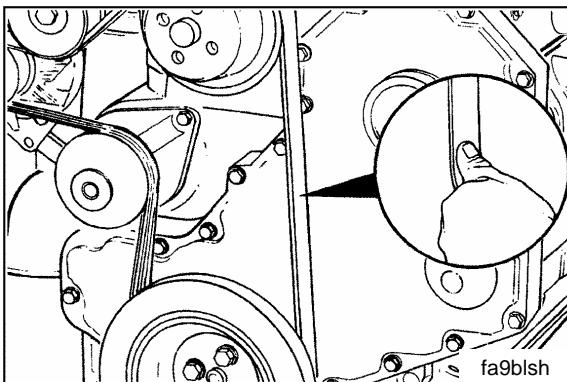
NOTE: Most compression leakage can be prevented by applying a small amount of oil to the mounting section of the adapter.



 Crank the engine with the starting motor. Read the gauge when the pointer is stabilized.

Engine Compression

KPa	psi
1965	285
2944	427



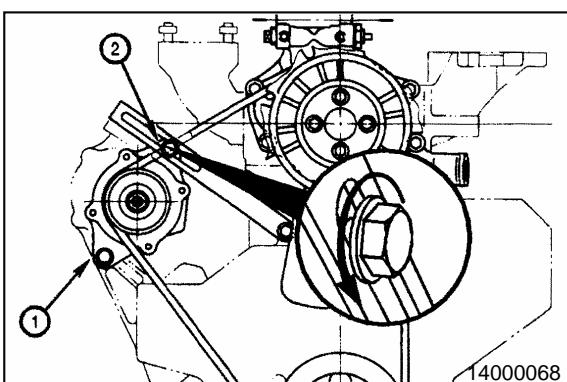
Testing and Adjusting the Fan Belt Tension

Testing the Fan Belt Tension

 Check the amount the fan belt deflects when pushed with a force of 6 kg [13.2 lb] at a point midway between the fan pulley and the alternator pulley.

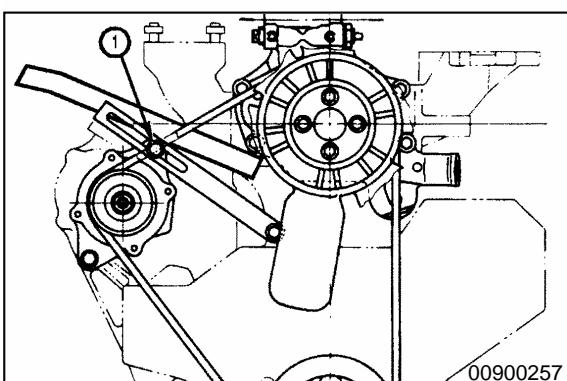
Fan Belt Deflection

mm	in
7.0	0.28
10.0	0.39



Adjusting the Fan Belt Tension

 Loosen the mounting capscrew of the alternator (1) and belt tension adjustment capscrew (2).



 Using a bar, raise the alternator, and adjust the fan belt tension.

 Tighten the adjustment capscrew and the mounting capscrew.

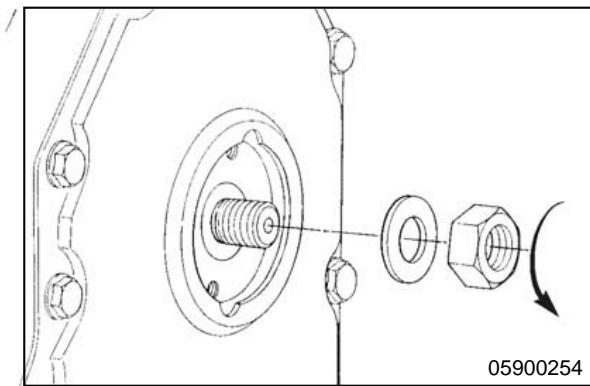
Torque Value:

Adjustment Capscrew 31 N•m [23 ft-lb]

Mounting Capscrew 66 N•m [49 ft-lb]

Fuel System

Fuel Injection Pump, Rotary



CAUTION

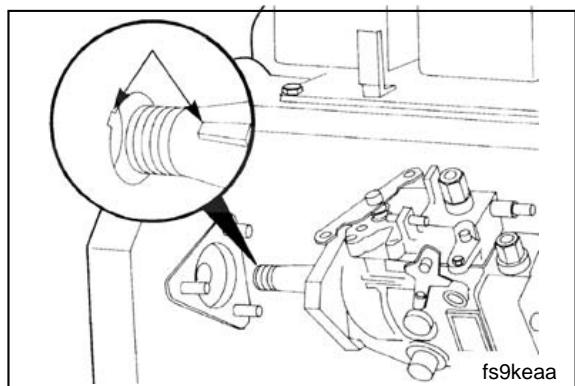


Do not drop the nut, washer, or key. Failure to do so will result in the need to remove the front gear cover.

Remove the gear cover access cap.

Rotate the engine until the keyway is vertical.

Remove the nut and washer from the fuel injection pump shaft.

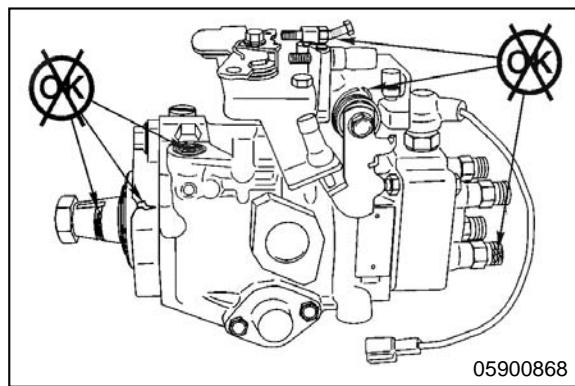


Remove the injection pump support bracket.

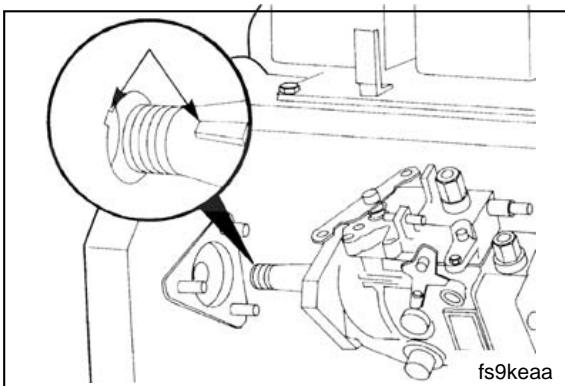
Remove the two mounting capscrews.

Remove the fuel injection pump.

Remove the key.



Inspect the fuel injection pump body for cracks or other damage



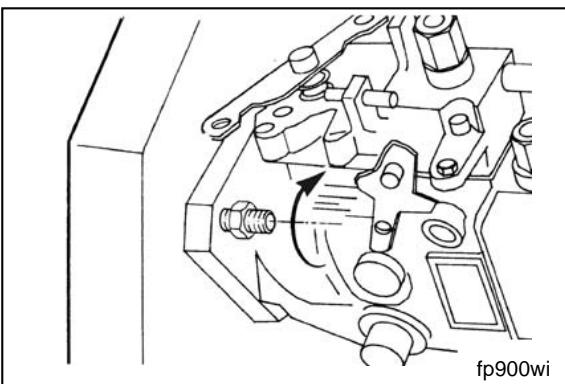
⚠ CAUTION

Make sure the key does not fall into the gear housing. Failure to do so can result in engine damage.

Install the Woodruff key into the fuel injection pump.

Align the key in the fuel injection pump with the keyway in the injection pump gear.

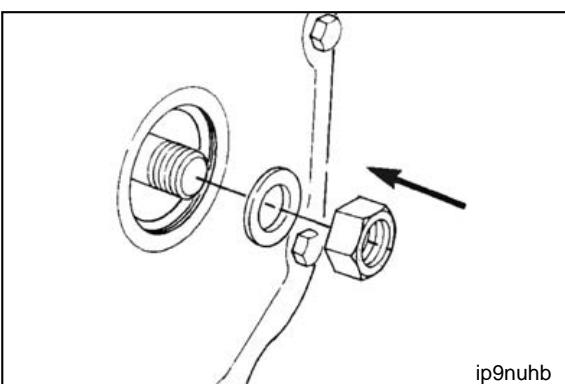
Install the fuel injection pump.



⚠ CAUTION

Do not attempt to pull the pump flange into the gear housing with the mounting nuts. Damage to fuel pump housing can occur.

Hand tighten the mounting nuts. The fuel pump must be free to move in the slots.

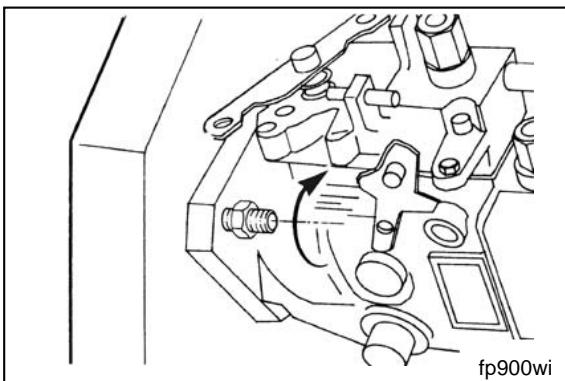


Install the fuel injection pump washer and nut..

Torque Value : 70 n.m [52 ft-lb]



Refer to the rotary fuel injection timing in this procedure to make sure the fuel pump is timed correctly.



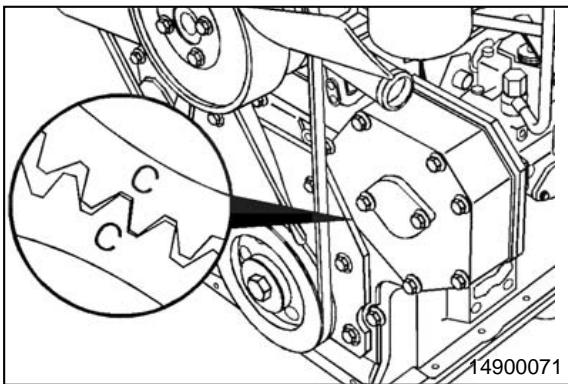
Tighten the fuel injection pump mounting capscrews.

Torque Value: 31 n.m [23 ft-lb]



Install the mounting bracket capscrews.

12 mm 19 n.m [14 ft-lb]
14 mm 31 n.m [23 ft-lb]



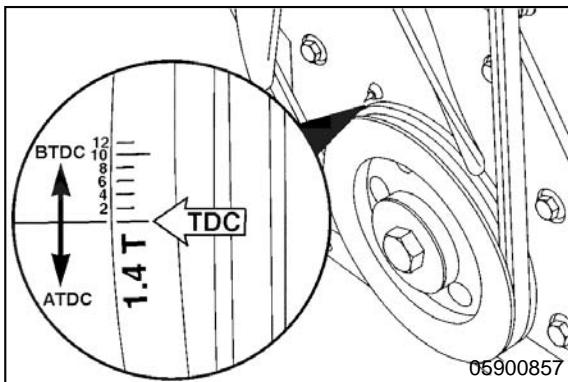
Install the fuel pump drive access cover.



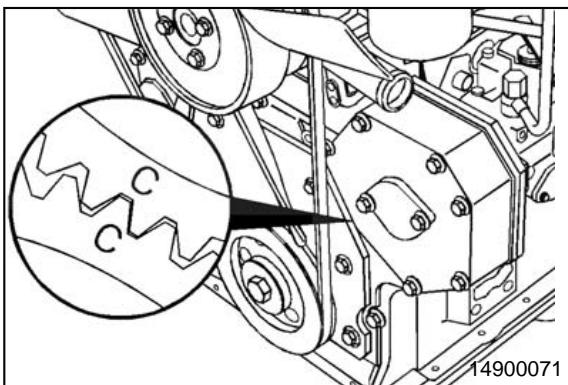
Tighten the two capcrews.

10 mm 13 n.m [10 ft-lb]

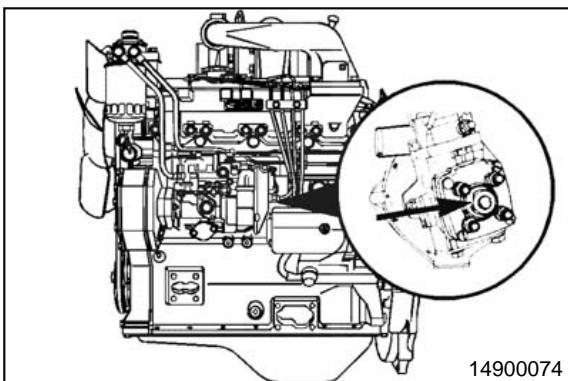
12 mm 19 n.m [14 ft-lb]



Set the number 1 cylinder at compression top dead center (TDC) by aligning the pointer on the gear cover to the TDC line on the crankshaft pulley.

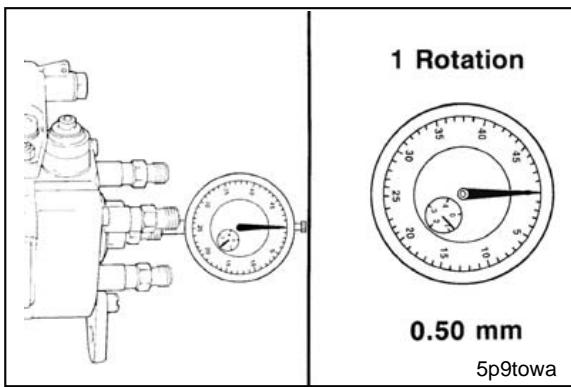


The fuel pump drive access cover can be removed to confirm the timing marks are aligned between the fuel pump drive gear and the idler gear if easier than removing the valve cover. This is to confirm that the engine is at TDC.



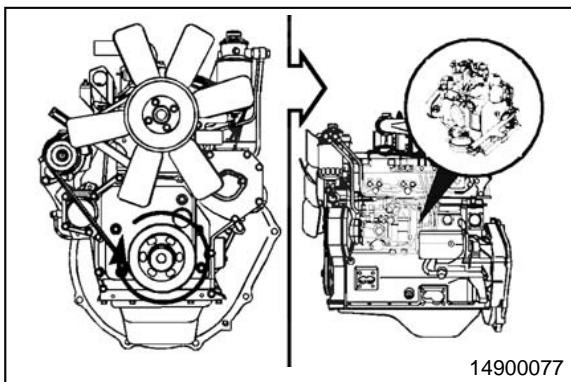
Remove the distributor head bolt and copper washer from the injection pump.

Discard the copper washer.



NOTE: Check that the stylus end of the dial gauge contacts the plunger head and is not bottomed out.

Install the dial gauge, Part Number 3377259, or equivalent, into the distributor head.

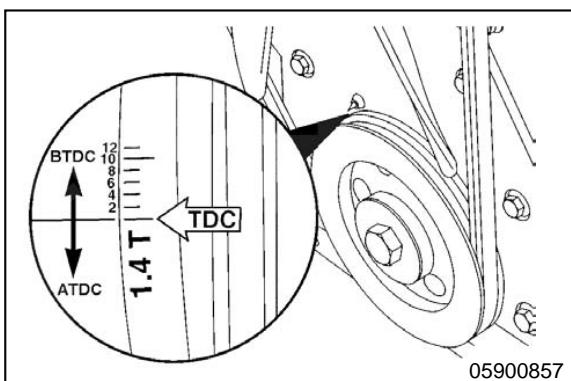


Rotate the crankshaft in the opposite direction of normal engine rotation (counterclockwise) slightly, until the dial gauge stops moving.

Set the dial gauge pointer to zero (0).

Slowly rotate the crankshaft in the normal direction of engine rotation until the dial indicator reads the following:

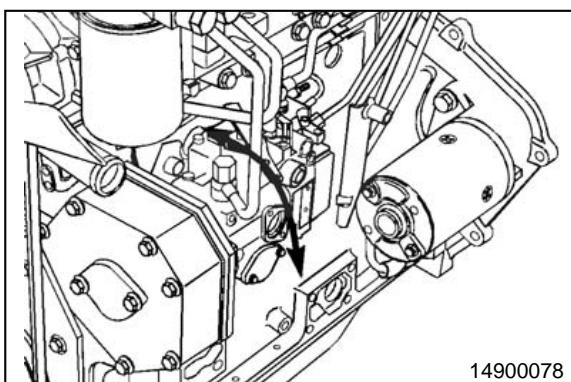
Measurements		
	mm	in
Distributor Head Timing	1.0±0.3	0.04±0.01



Check the degree markings on the crankshaft pulley with the pointer and that is the timing of the engine.

If the timing needs to be adjusted, rotate the crankshaft approximately 45 degrees in the reverse direction of engine rotation.

Rotate the crankshaft in the normal direction of engine rotation until the pointer on the gear cover lines up with the correct timing mark on the crankshaft pulley as stated on the dataplate.

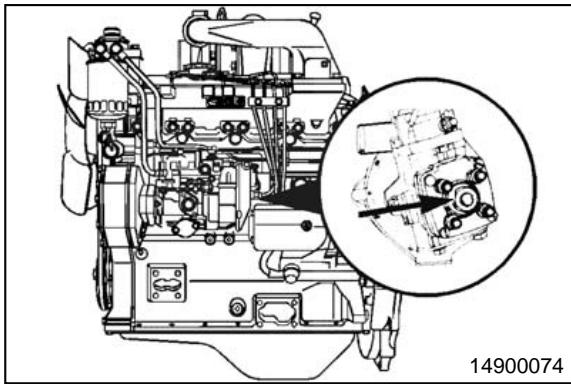


Loosen the fuel injection pump support bracket, then loosen the injection pump mounting capscrews.

Rotate the fuel pump until the dial indicator reads 1.0 ± 0.3 mm [0.04 ± 0.01 in].

Tighten the fuel injection pump mounting capscrews, then the support bracket.

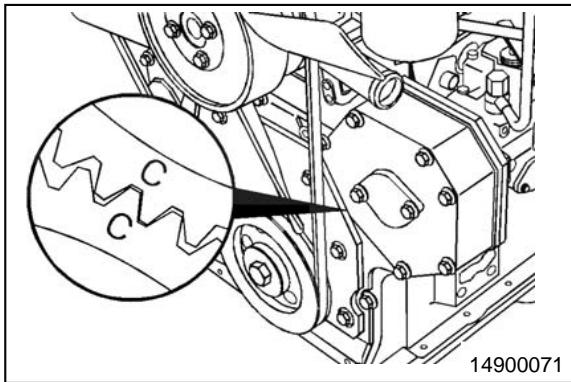
Torque Value: 31 n.m [23 ft-lb]



Remove the dial gauge.

Install the distributor head bolt and new copper washer into the fuel injection pump.

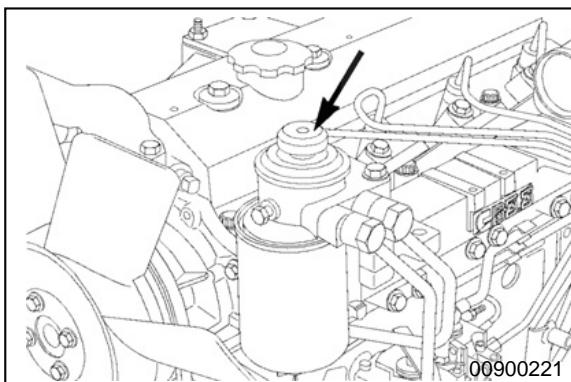
Torque Value: 17 n.m [13 ft-lb]



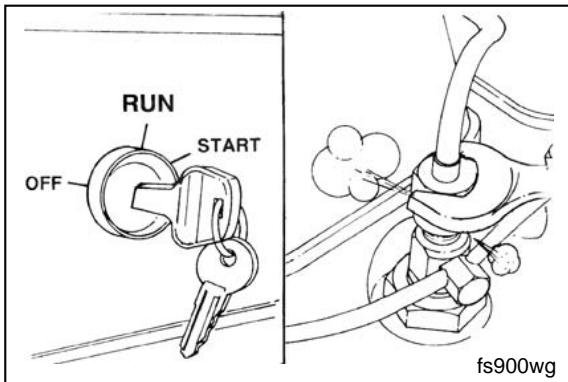
Install the fuel pump drive access cover.

10 mm 13 n.m [10 ft-lb]

12 mm 19 n.m [14 ft-lb]



If the fuel lines are opened, the low-pressure lines can be vented by pumping the hand lever on the fuel filter head.



⚠️ WARNING

Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

⚠️ WARNING

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

Vent the high-pressure fuel lines.

Loosen the fitting at the number 1 injector.

Place the fuel control in the run position.

Crank the engine so air can vent from the fuel lines.

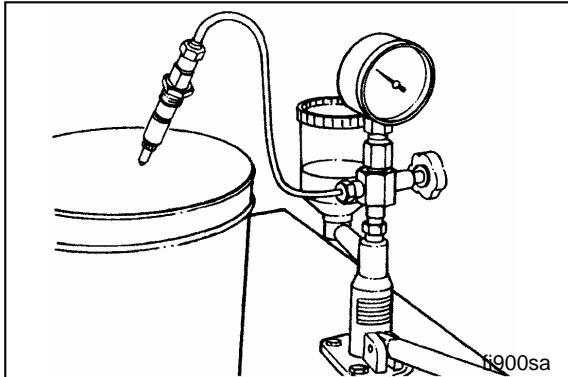
Tighten the fitting.

Torque Value: 30 n.m [22 ft-lb]

Continue this process through the remaining three injectors until the engine runs smoothly.

Injector

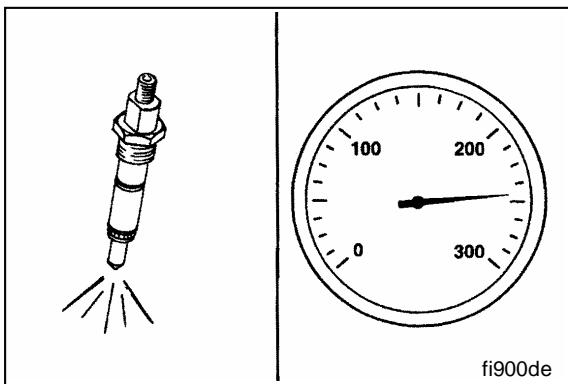
Testing



⚠️ WARNING

Keep your body clear of test spray. Fluid can be injected into the bloodstream causing blood poisoning and possible death.

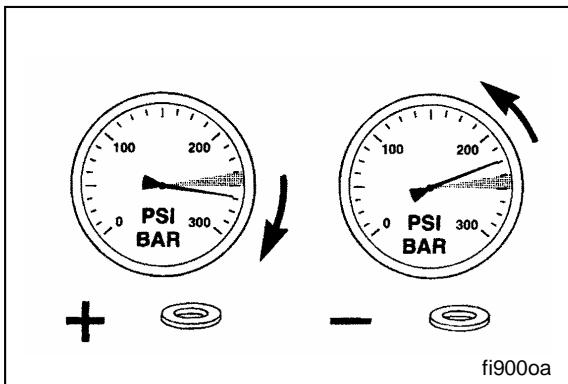
NOTE: All nozzles must be tested for opening pressure, chatter and spray pattern.



Check the opening pressure.

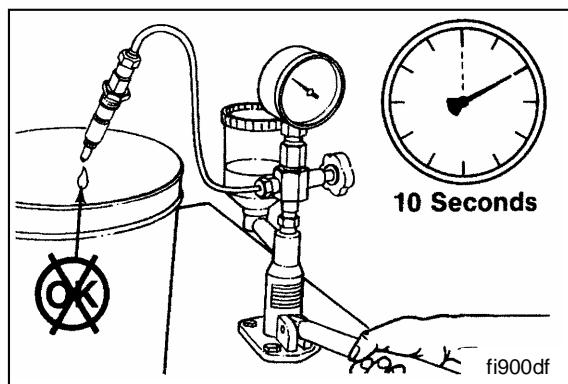
- Open valve.
- Operate lever at one stroke per second.
- Read pressure indicated when spray begins.

Nominal Injector Opening Pressure: 19.6 Mpa
[2843 psi]



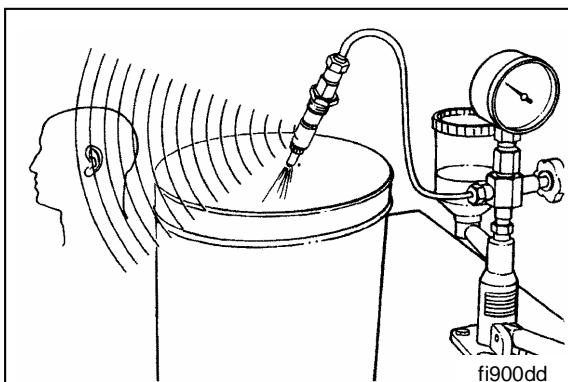
If the opening pressure is out of specification, disassemble the injector and change the shims in order to change the opening pressure.

NOTE: .01 mm [0.0039 in] shim thickness equals 41 bar [595 psi].



Leakage Test

- Open the valve.
- Operate the lever to hold pressure 20 bar [290 psi] below opening pressure.
- No drops should fall from the tip within 10 seconds.



Chatter Test

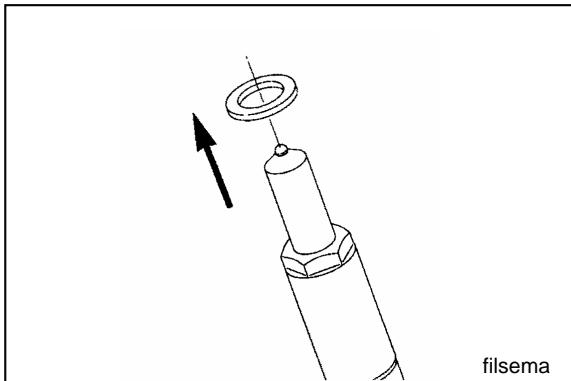
The chatter test indicates the ability of the needle valve to move freely and correctly atomize the fuel. An audible sound should be heard as the valve rapidly opens and closes. A well optimized spray pattern should be seen.

Used nozzles should **not** be evaluated for chatter at lower speeds. A used nozzle can generally be used if it passes the leakage test.



Disassembly

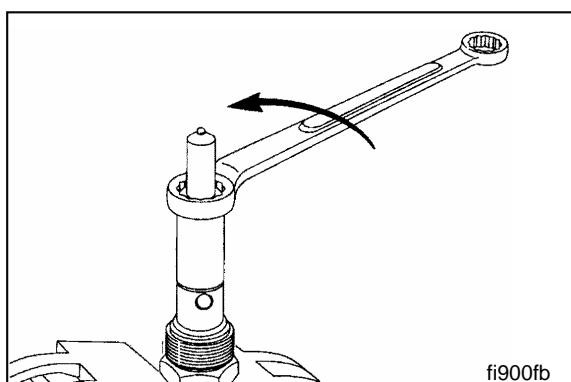
Remove the copper sealing washer and discard.



filsema



Clamp the nozzle holder in a soft jawed vise and remove the nozzle nut.

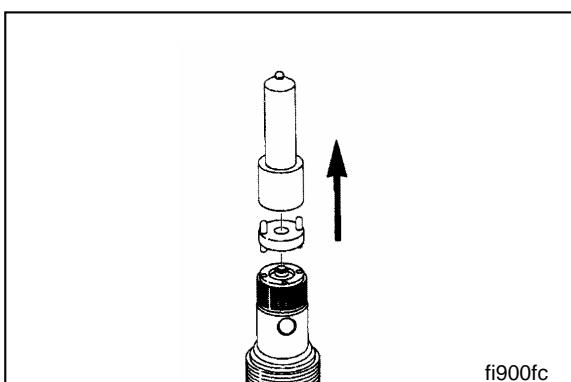


fi900fb



Remove the nozzle needle valve and intermediate plate.

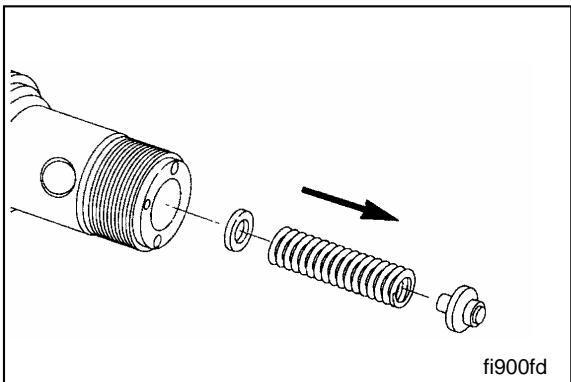
NOTE: To avoid damage, place the injector nozzle and needle valve in a suitable bath of clean test oil.



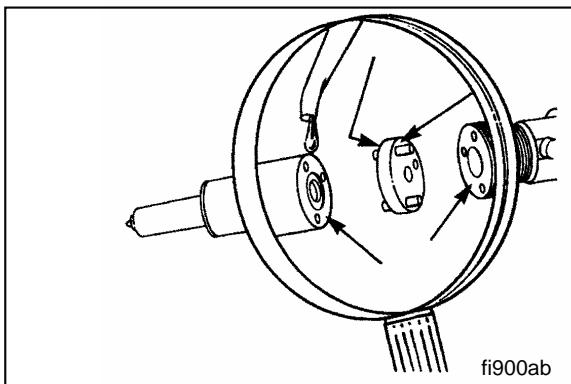
fi900fc



Remove the nozzle holder from the vise; then remove the pressure spindle, pressure spring, and shims.



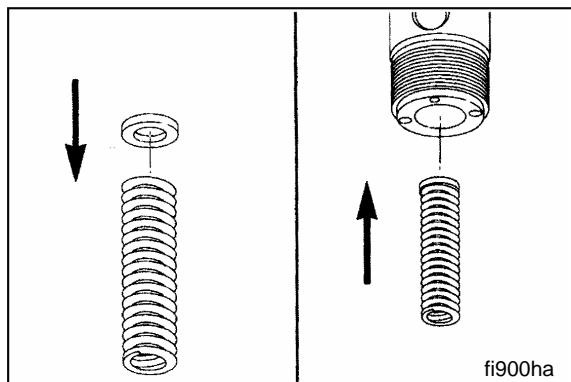
fi900fd



Assembly



NOTE: Make sure all mating surfaces and pressure faces are clean and lubricated with fuel oil before assembly.

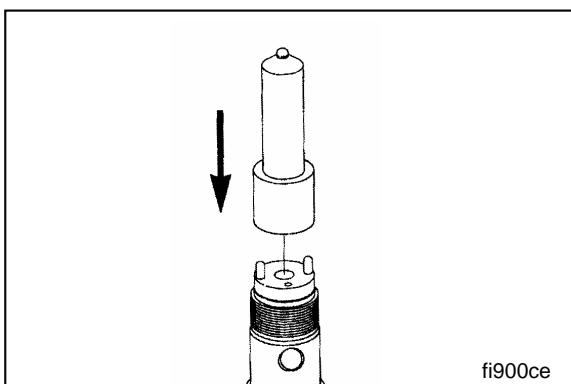


WARNING

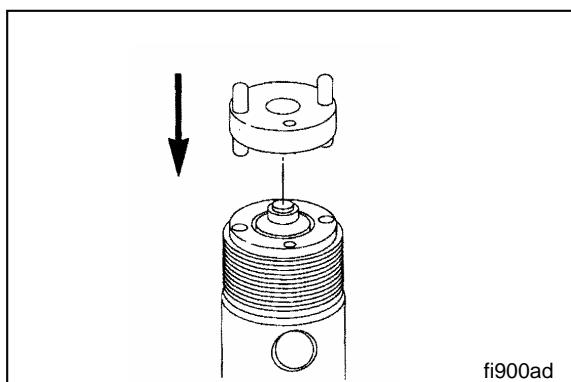


Install the same thickness of shims that were removed in disassembly. Use the pressure spring to make sure the shims are installed flat.

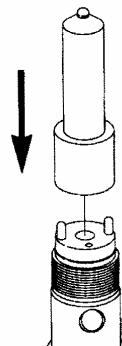
Install the shims.



Clamp the nozzle holder in a soft jawed vise and install the spindle.



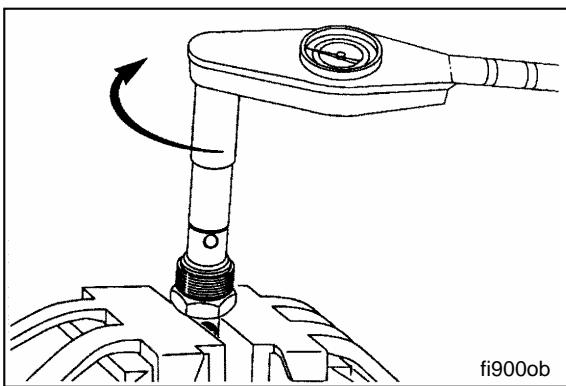
Install the intermediate plate.



fi900ce



Install the needle valve and nozzle assembly.



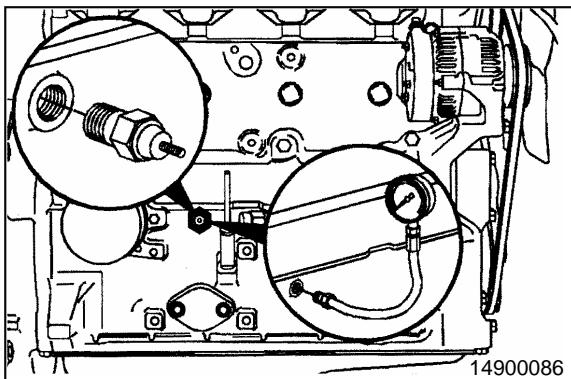
fi900ob



Install the nozzle nut.

Lubricating System

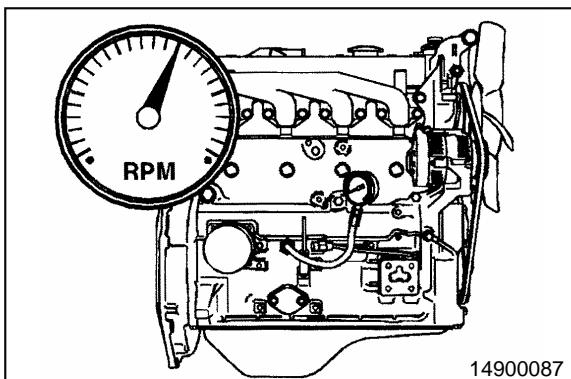
Measuring Oil Pressure



WARNING

When measuring the oil pressure, be careful not to get caught in rotating parts. always remove or install plug or oil pressure gauges with the engine stopped.

Remove the oil pressure sensor, and install the pressure gauge.

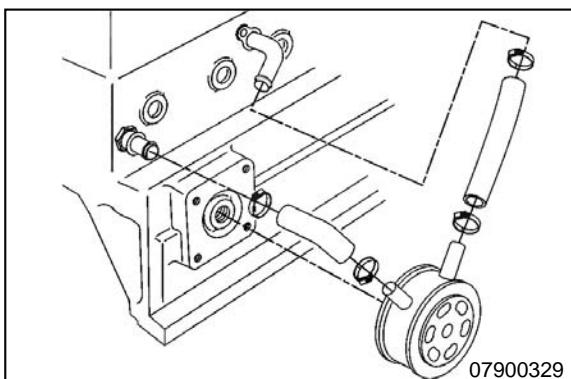


NOTE: Measure the oil pressure while the engine is warm (oil temperature minimum: 82° C [180° F]).

Start the engine, and measure the oil pressure.

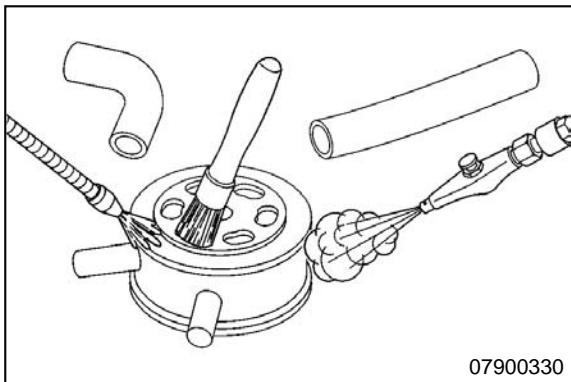
Lubricating Oil Pressure		
kPa		ft-lb
210	MIN	30
700	MAX	102

Lubricating Oil Cooler (If equipped)



Disconnect the two cooling lines from the cylinder block and the lubricating oil cooler.

Remove the lubricating oil cooler (horizontal mount) from the cylinder block.



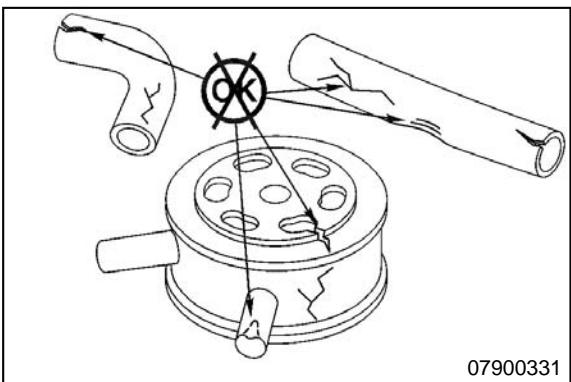
07900330

⚠️ WARNING

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the lubricating oil cooler housing and hoses with a strong solution of detergent in hot water.

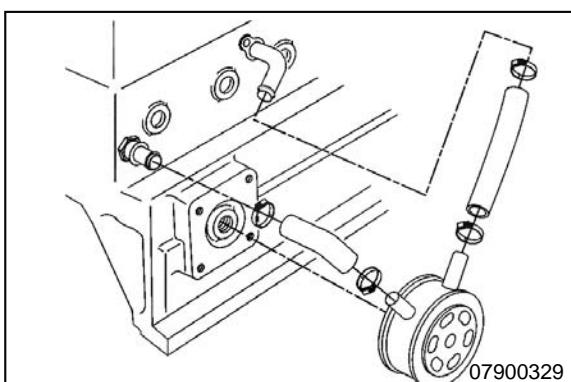
Dry the components with compressed air.



07900331



Inspect the lubricating oil cooler and hoses for cracks or other damage.



07900329



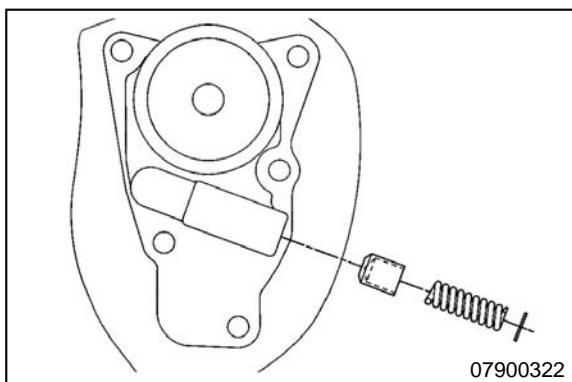
Install the lubricating oil cooler (horizontal mount) on the lubricating oil filter head adapter.



Torque Value: 79 n.m [58 ft-lb]

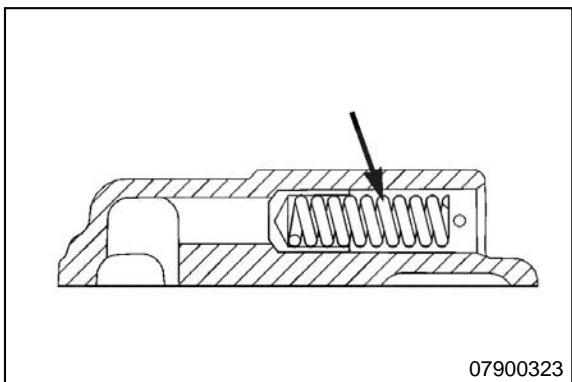
Connect the two cooling lines to the cylinder block and the lubricating oil cooler.

Lubricating Oil Pressure Regulator (Main Rifle)



Remove the pin that holds the regulator spring and valve in the lubricating oil pump.

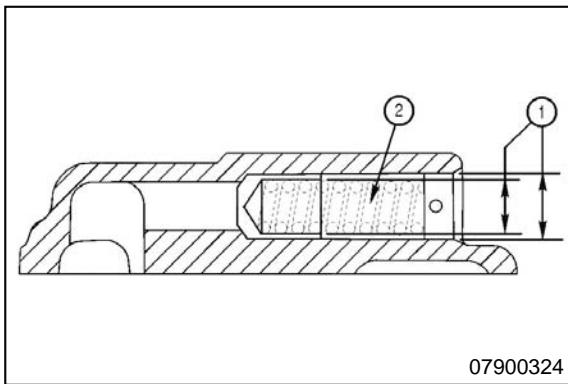
Remove the lubricating oil pressure regulator from the lubricating oil pump.



Inspect the valve spring and body for damage or excessive wear.

Inspect the valve for scoring.

Replace the lubricating oil pump if damage is found.



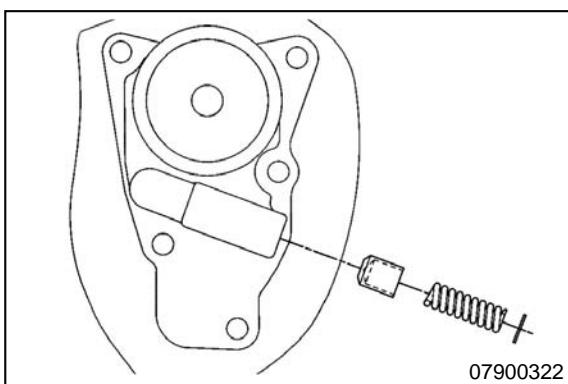
Measure the clearance between the regulator body and valve (1).

Valve and Body Clearance				
	Standard Size	Tolerance		Standard Clearance
		Valve	Body	
1	11 mm [0.43 in]	0.050 mm to -0.077 mm [0.002 in] to [0.003 in]	0.020 mm to -0.020 mm [0.008 in] to [0.008 in]	0.030 to 0.097 mm [0.001 in] to [0.004 in]

Measure the valve spring length (2).

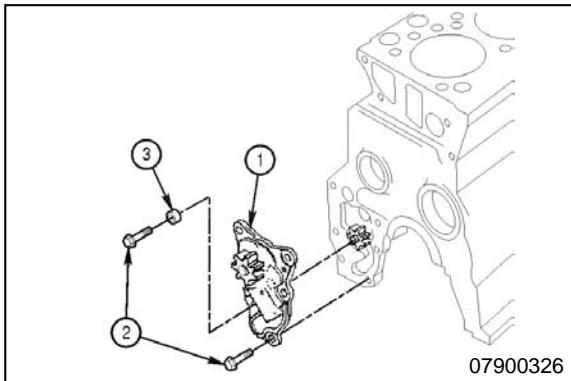
Valve Spring Length					
		Standard	Repair Limit		
		Free Length	Installed Length	Installed Load	Free Length
2	A	33.1 mm [1.30 in]	27.8 mm [1.09 in]	2.44 kg [5.38 lb]	N/A

Replace the lubricating oil pump if not within specification.



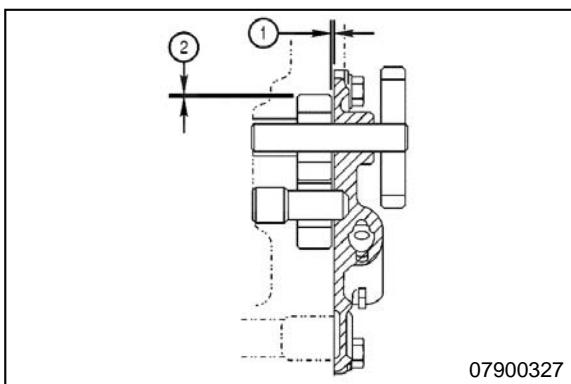
Install the lubricating oil pressure regulator assembly into the lubricating oil pump.

Install the retaining pin that holds the regulator in the lubricating oil pump.



Remove the five mounting capscrews (2) and spacer (3).

Remove the lubricating oil pump (1).

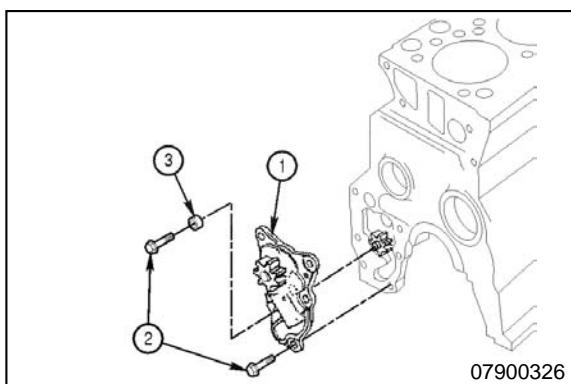


Inspect the lubricating oil pump housing for damage.



Measure the axial (1) and radial (2) clearance.

Axial and Radial Pump Gear Clearance			
	Inspection Item	Standard	Clearance Limit
1	Axial	0.030 to 0.085 mm [0.0012 to 0.0033 in]	0.10 mm [0.0039 in]
2	Radial	0.045 to 0.090 mm [0.0018 to 0.0035 in]	0.13 mm [0.0051 in]



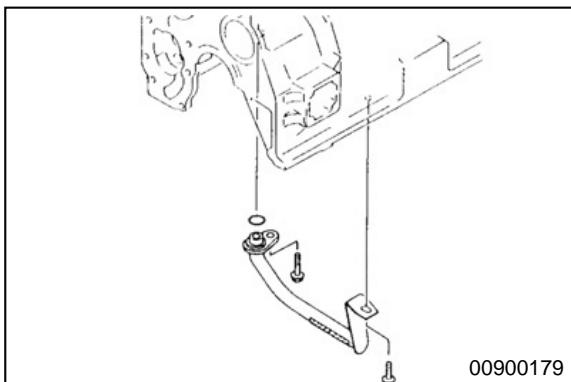
Install the lubricating oil pump (1).



Install the spacer (3) and five mounting capscrews (2).
Tighten the capscrews.

Torque Value: 19 n.m [14 ft-lb]

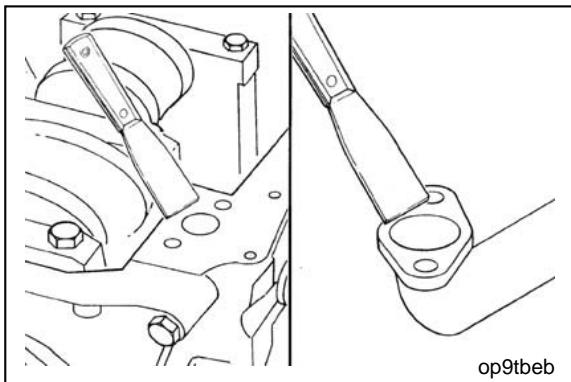
Lubricating Oil Suction Tube (Block-Mounted)



Remove the two mounting capscrews from the lubricating oil suction tube.

Remove the lubricating suction tube and o-ring from the cylinder block.

Discard the o-ring.



⚠️ WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ WARNING

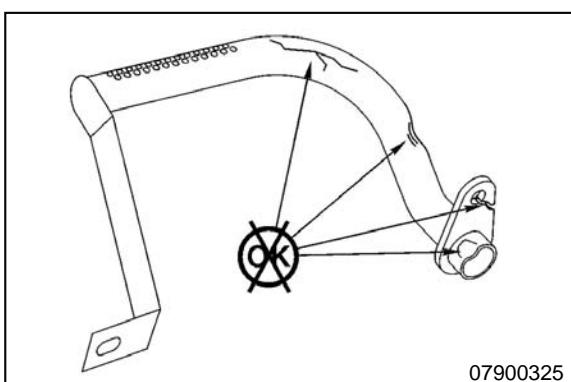
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠️ WARNING

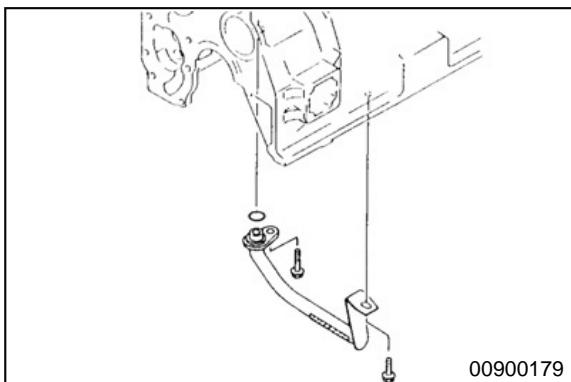
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the lubricating oil suction tube and o-ring surfaces.

Dry with compressed air.



Inspect the lubricating oil suction tube for cracks or other damage.



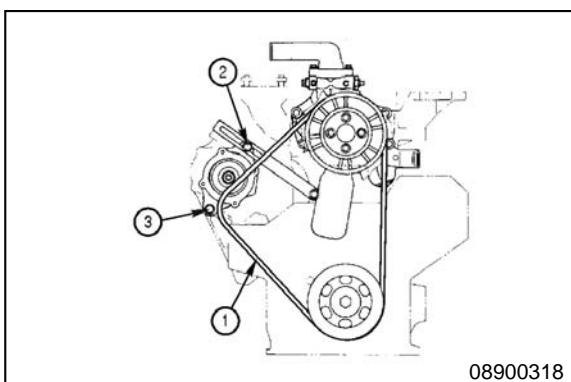
Install the o-ring and lubricating suction tube onto the cylinder block.



Install the two mounting capscrews into the lubricating oil suction tube. Tighten the capscrews.

Torque Value: 19 n.m [14 ft-lb]

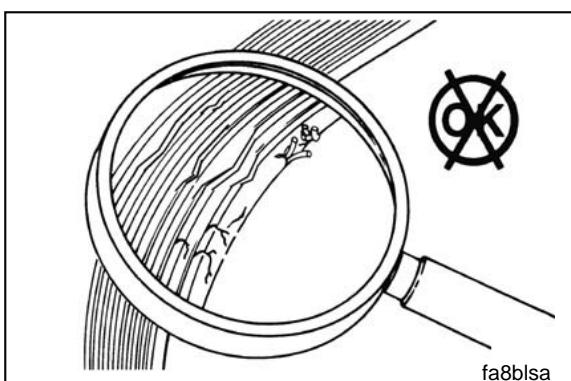
Cooling System



Loosen the alternator mounting capscrew (3) and the belt tension adjustment capscrew (2).

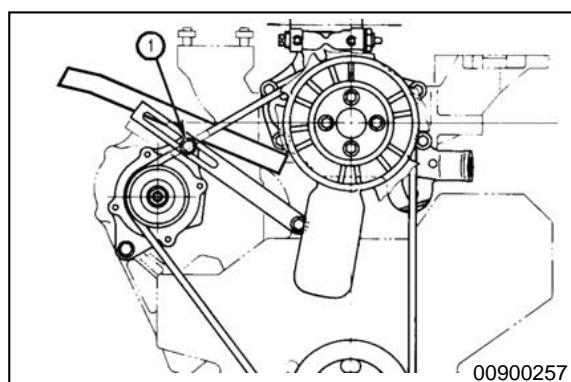
Move the alternator down the adjustment bar until the drive belt is loose.

Remove the drive belt (1).



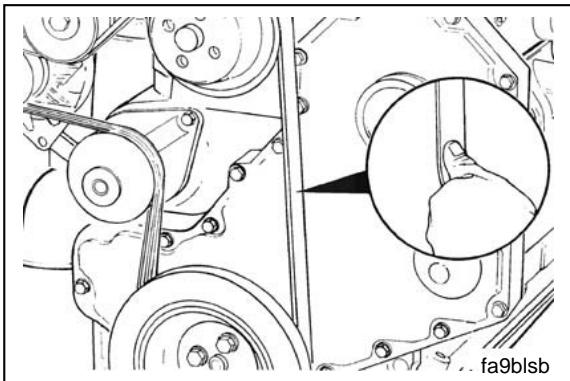
Inspect the drive belt for the following:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.



Install the drive belt.

Using a breaker bar, raise the alternator on the adjustment bar (1), and adjust the fan belt tension to specification.

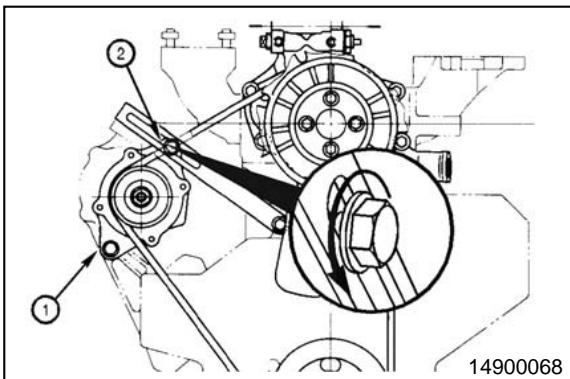


Measure the belt tension in the center span of the pulleys.

Check the belt tension using a click-type belt tension gauge, Part Number 3822524, or equivalent, or a Burroughs gauge, Part Number ST-1138, or equivalent.

Fan Belt Deflection

	n	lb
New Belts	324	MIN
	378	MAX
Used Belts	216	MIN
	270	MAX



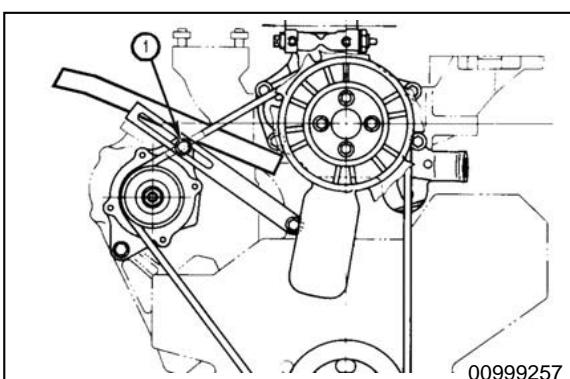
Loosen the mounting capscrew of the alternator (1) and belt tension adjustment capscrew (2).



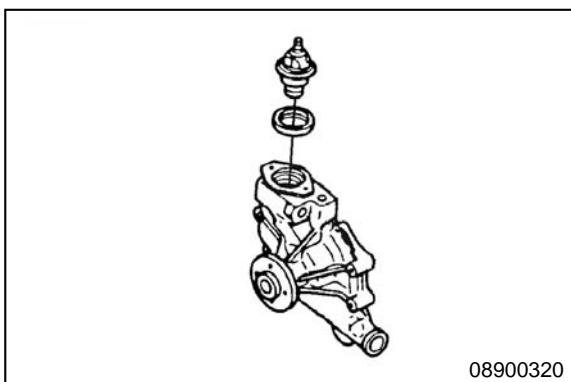
Using a breaker bar, raise the alternator, and adjust the fan belt tension to specification.

Tighten the adjustment capscrew and the mounting capscrew.

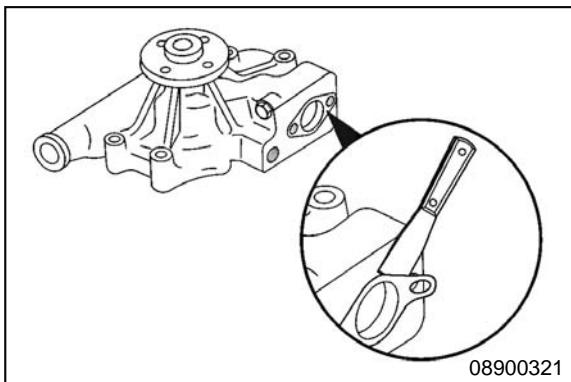
Adjustment Capscrew 31 n.m [23 ft-lb]
Mounting Capscrew 66 n.m [49 ft-lb]



Coolant Thermostat



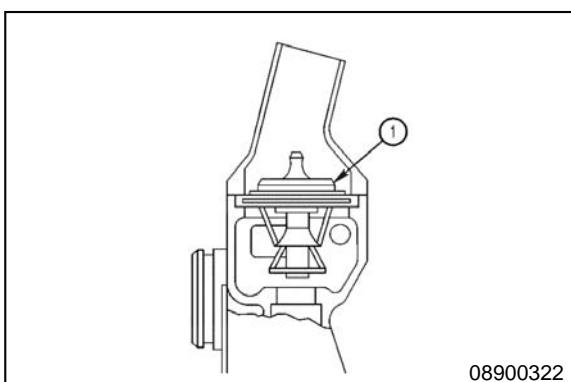
Remove the thermostat and seal from the water pump cavity.



CAUTION

Do not let dirt or debris fall into the thermostat cavity when cleaning the gasket surfaces. Failure to do so can cause engine damage.

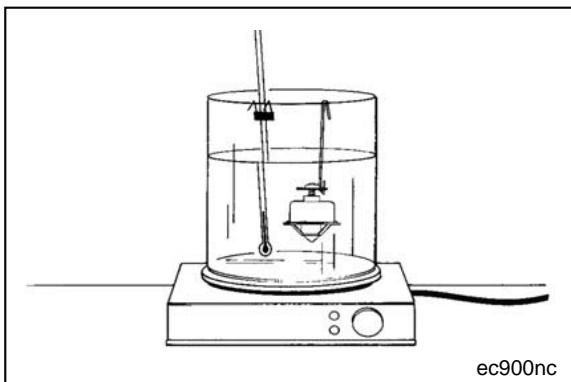
Clean the mating surfaces.



Inspect the thermostat (1) for damage such as obstructions caused by debris, broken springs, or stuck or missing vent pins.



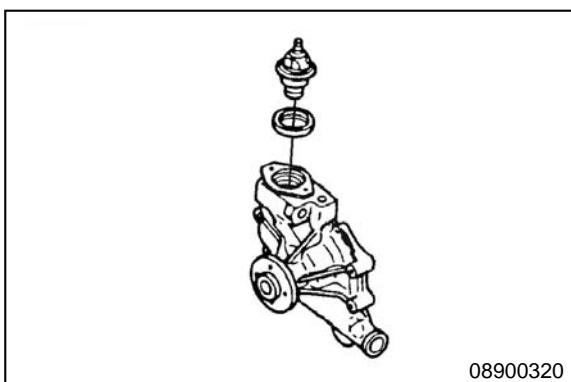
Make sure the thermostat is clean and free from corrosion.



 **NOTE:** Do not allow the thermostat or thermometer to touch the side of the container.

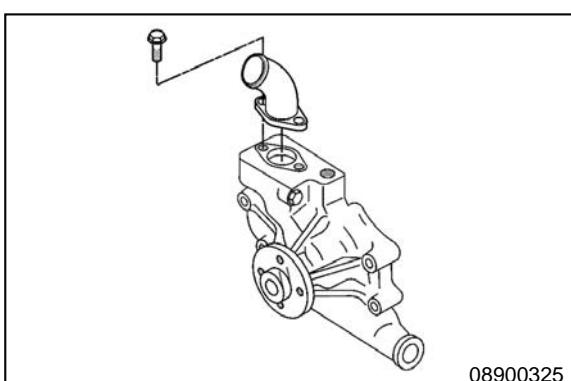
Suspend the thermostat and a 100°C [212°F] thermometer in a container of well-mixed water.

Heat the water slowly at a temperature of 77°C [171°F] so the wax element in the thermostat has sufficient time to react to the rising water temperature. The thermostat thermal open lift is 8 mm [0.315 in] when immersed in hot water for 4 to 5 minutes.

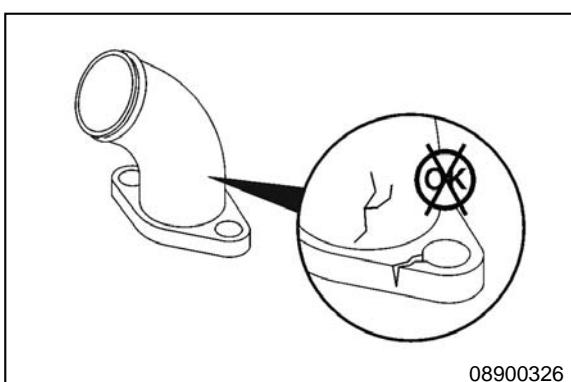


Install the seal and thermostat into water pump cavity.

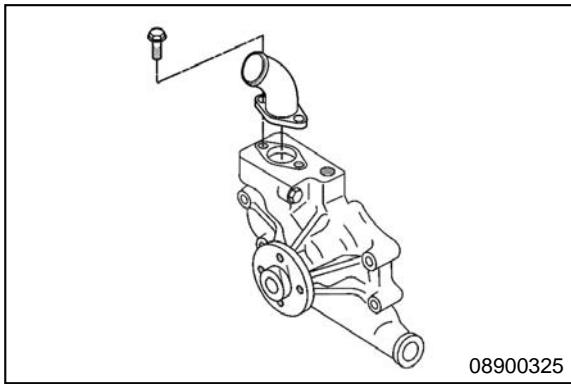
Coolant Thermostat Housing



Remove the two capscrews and the thermostat housing from the water pump.



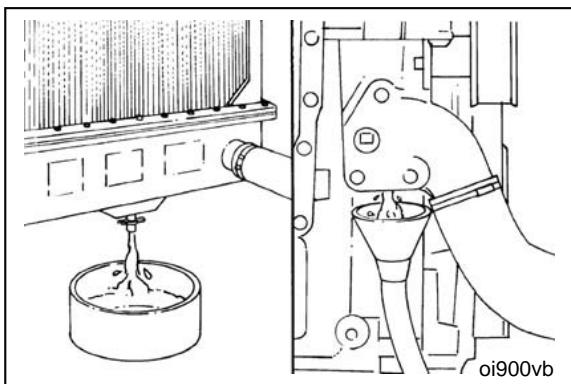
Inspect the thermostat housing for cracks or other damage.



Install the thermostat housing onto the water pump.



Cooling System



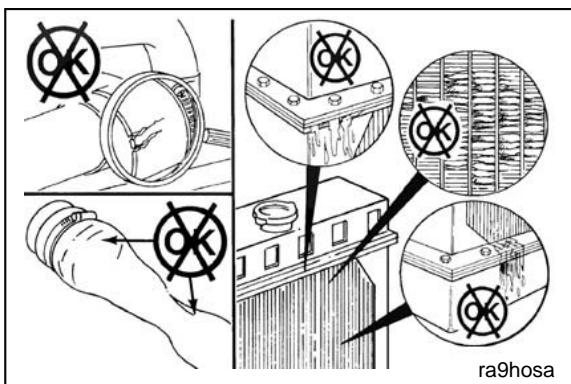
⚠️ WARNING

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠️ WARNING

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

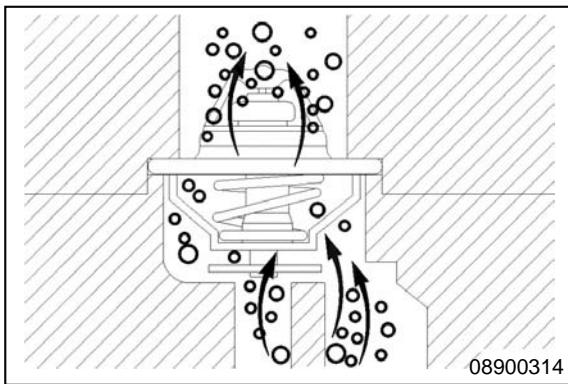
Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet. A drain pan with a capacity of 20 liters [5 gal] will be adequate in most applications.



Check for damaged hoses and loose or damaged hose clamps. Replace, as necessary.

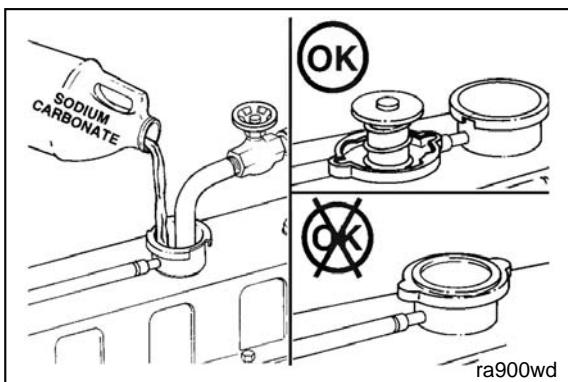


Check the radiator for leaks, damage, and buildup of dirt. Clean and repair, as necessary.



During filling, air must be vented from the engine coolant passages. The air vents through the "jiggle pin" openings to the top radiator hose and out the fill opening. Additional venting is provided for engine equipped with a aftercooler. Open the petcock during filling.

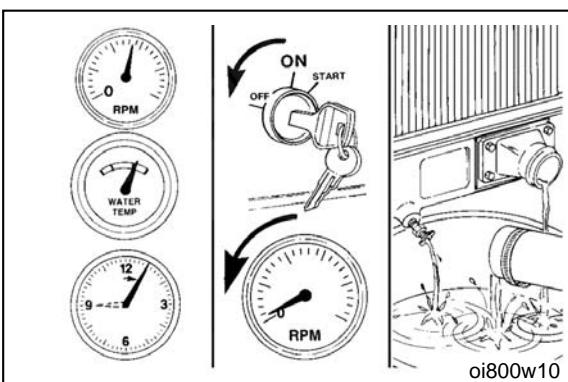
Adequate venting is provided for a fill rate of 10 liters/minute [2.6 gal/minute].



NOTE: Do not install the radiator cap. The engine must be operated without the cap for this process.

Fill the system with a mixture of sodium carbonate and water (or a commercially available equivalent).

Use 0.5 kg [1.0 lb] of sodium carbonate for every 23 liters [6 gal] of water.

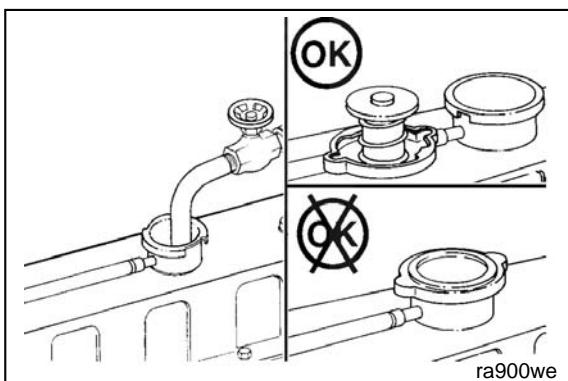


⚠️ WARNING

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine for 5 minutes with a coolant temperature above 82°C [180°F].

Shut the engine off, and drain the cooling system.



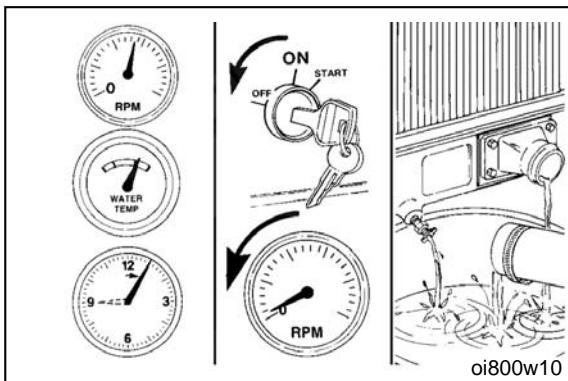
⚠️ CAUTION

The cooling system must be filled properly to prevent air locks in the cooling passages. Failure to vent the cooling system properly, can cause damage to the cooling system.

Fill the cooling system with clean water.

Make sure to vent the engine and aftercooler (if equipped) for complete filling.

Do not install the radiator cap.



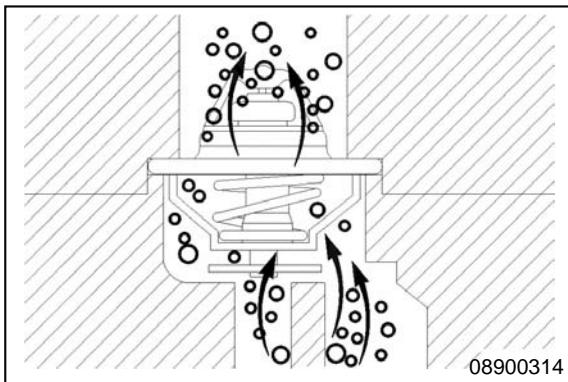
⚠ WARNING

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine for 5 minutes with a coolant temperature above 82°C [180°F].

Shut the engine off, and drain the cooling system.

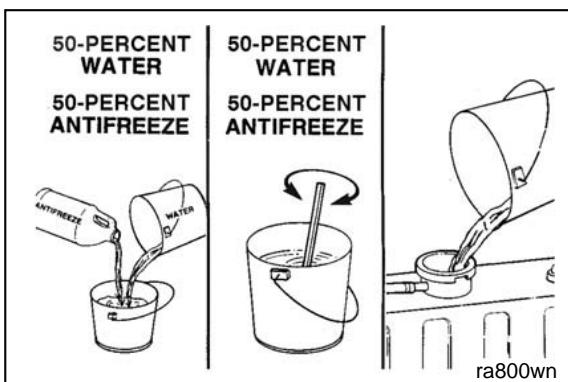
If the water being drained is still dirty, the system must be flushed again until the water is clean.



⚠ CAUTION

The cooling system must be filled properly to prevent air locks in the cooling passages. Failure to vent the cooling system properly, can cause damage to the cooling system.

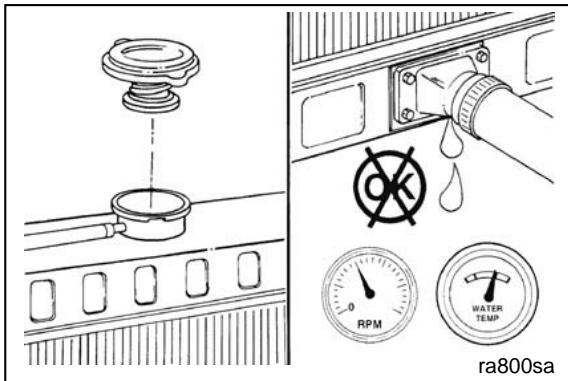
Adequate venting is provided for a fill rate of 10 liters/minute [2.6 gal/minute].



⚠ CAUTION

Do not use water alone for coolant. Damage from corrosion can severely damage the engine cooling system.

Use a mixture of 50-percent water and 50-percent ethylene glycol antifreeze to fill the cooling system.



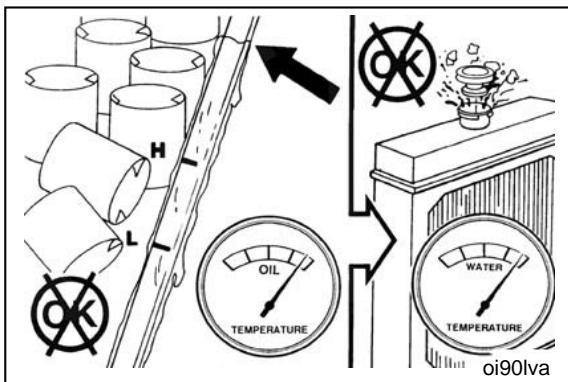
⚠️ WARNING

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

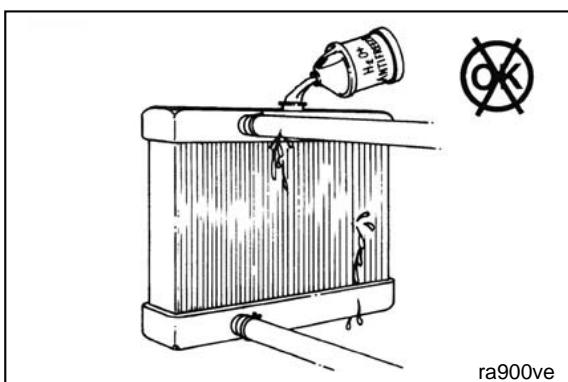
Install the pressure cap. Operate the engine until it reaches a temperature of 82°C [180°F], and check for coolant leaks.

Check the coolant level again to make sure the system is full of coolant, or that the coolant level has risen to the hot level in the recovery container on the system, if equipped.

Cooling System Diagnostics



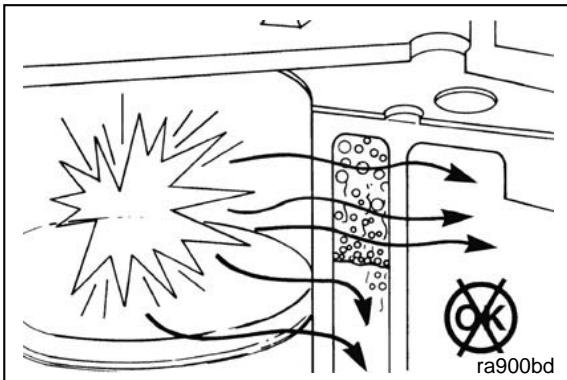
When you troubleshoot overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil.



Overfilling with oil raises the oil temperature that is transferred to the coolant system at the oil cooler.

The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

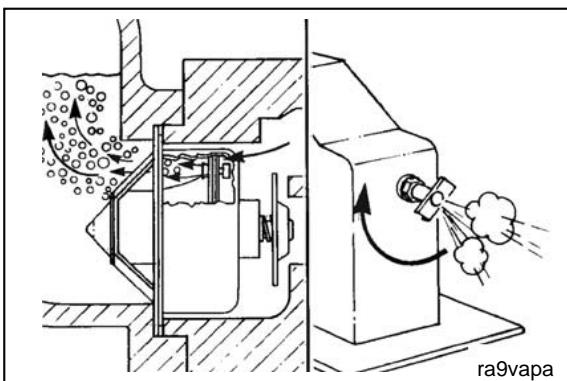
NOTE: The engine or system has a leak if frequent addition of coolant is necessary. Find and repair the leak.



! CAUTION

The engine coolant passages must be completely filled with coolant.

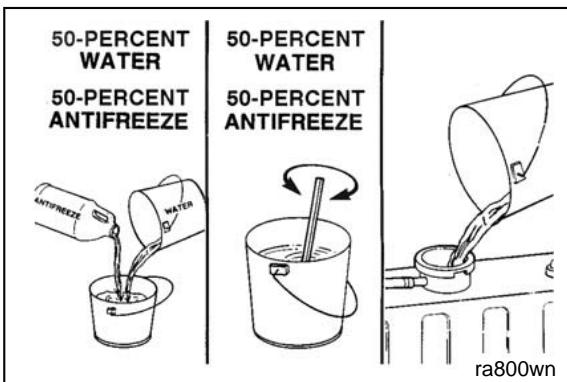
During operation, entrapped air mixes with the coolant, which results in cavitation corrosion and poor heat transfer. Highly aerated coolant can cause localized overheating of the cylinder head and block, which can result in a cracked head, scored cylinder, or blown head gasket.



During filling, air must be vented from the engine coolant passages. The air vents through the jiggle pin openings to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an aftercooler. Open the petcock during filling.

NOTE: Adequate venting is provided for a fill rate of 10 liters/minute [2.6 gal/minute].

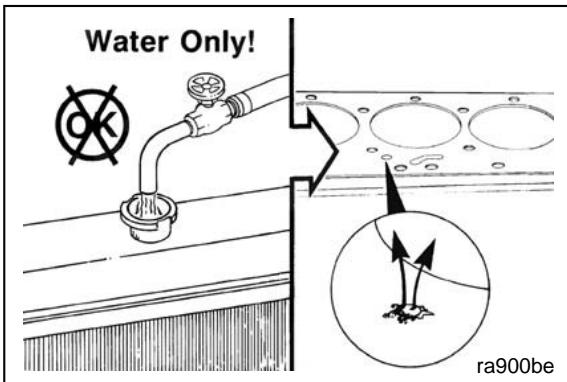
NOTE: Excess air in the cooling system can lead to overheating and low coolant levels.



NOTE: A 50-percent mixture of antifreeze and water must be premixed before filling the system. The ability of antifreeze to remove heat from the engine is not as good as water, so pouring antifreeze into the engine first could contribute to an overheated condition before the liquids are completely mixed.

A mixture of 50-percent ethylene-glycol base antifreeze is required for operation of the engine in temperature environments above -37°C [-35°F]. A mixture of 40-percent water and 60-percent antifreeze is recommended for temperatures below -37°C [-35°F]. Do not use more than 60-percent antifreeze.

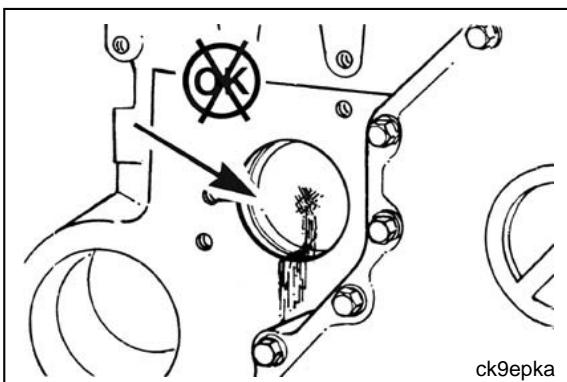
Refer to Cummins Coolant Requirements and Maintenance for additional cooling system information.



! CAUTION

Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant. The small holes in the head gasket are especially susceptible to plugging. These holes are orifices and their size is critical. Do not enlarge the size of the orifices. To do so will disturb the coolant flow and will not solve an overheating problem.

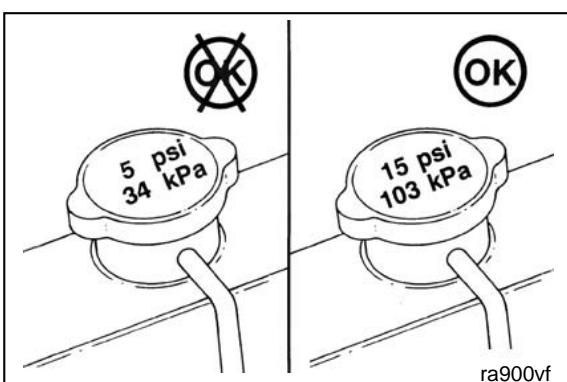
Water will cause rust formation, reducing the flow in the smaller coolant passages.



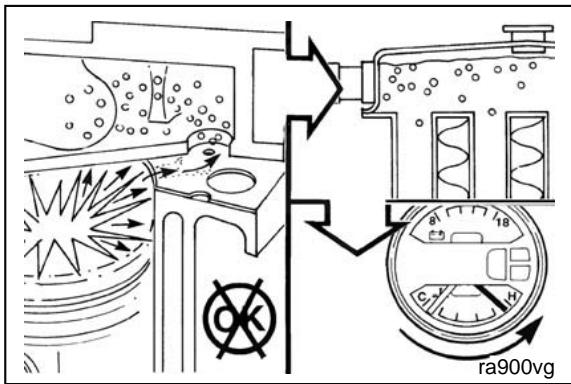
! CAUTION

A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bore.

Also, water used as a coolant for even a relatively short period can result in the cup plugs rusting through, allowing the coolant to leak.



An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.

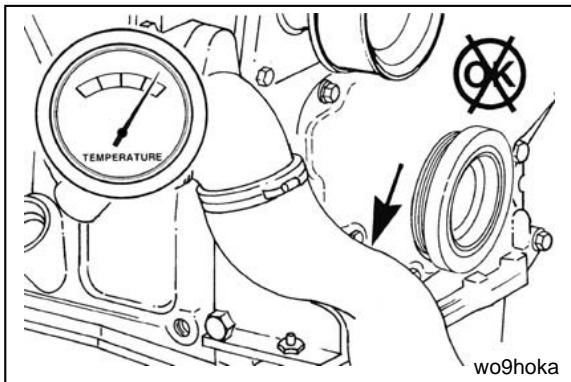


 Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

 Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.

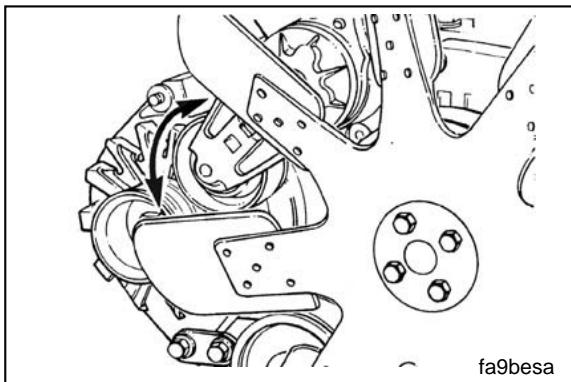
The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket, oil cooler, etc.

Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers.

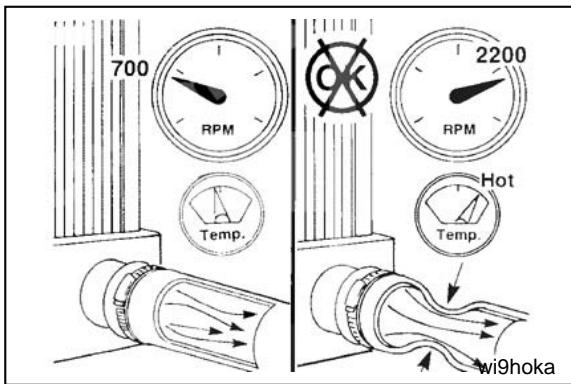


Water Pump

The water pump pulls coolant from the bottom of the radiator and pumps it through the engine back to the top of the radiator for cooling. Reduced or interrupted flow will result in the engine running hot.

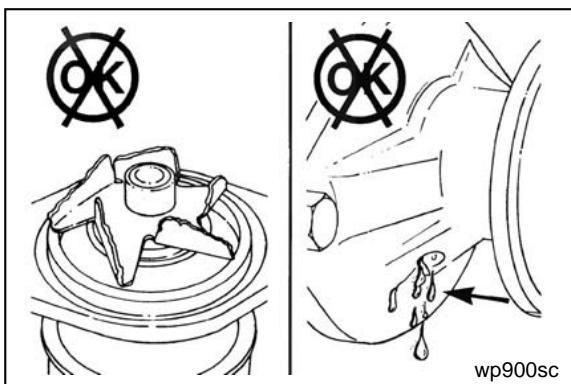


The pump is belt-driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed, reducing the amount of coolant flow.

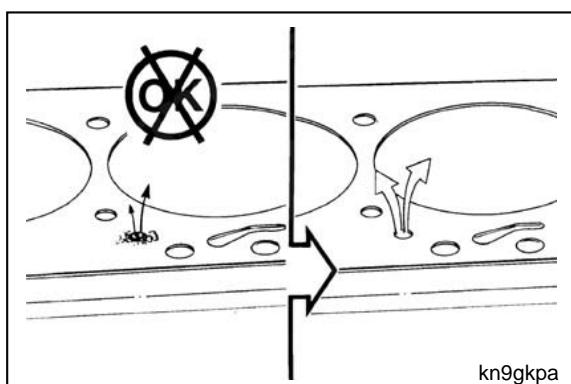


The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually not collapse while the engine is running at low speed. Check the hose while the engine is running at rated speed.

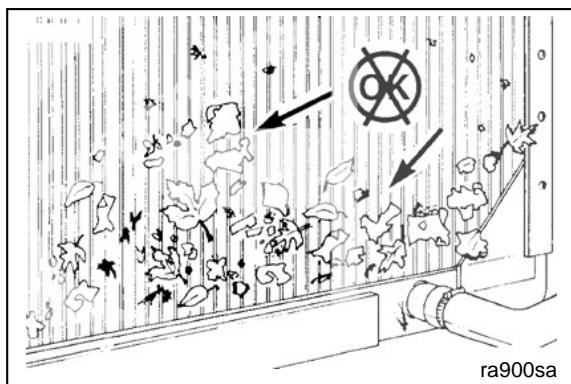
NOTE: Be sure the engine is warm, a minimum of 95°C [203°F], so the thermostat is open.



A worn or malfunctioning water pump will not produce the flow required to prevent the engine from running hot. However, be sure to check the other possibilities indicated in the Troubleshooting Logic before checking the flow or replacing the pump.



As stated in the coolant discussion, an obstruction in the passages can interrupt flow.

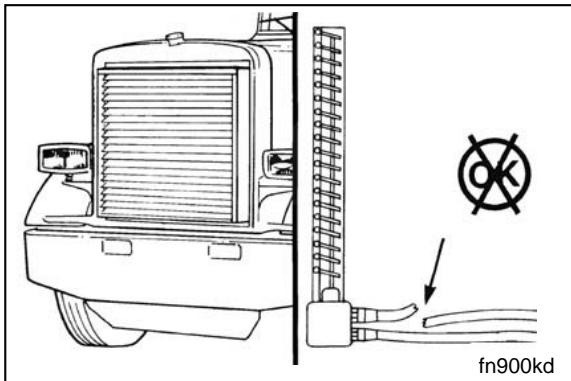


The following steps are for troubleshooting the Radiator, Fans, and Shutters:

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (paper, straw, lint, dust, etc.) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.

If the fan is belt-driven, a slipping belt will result in slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem.

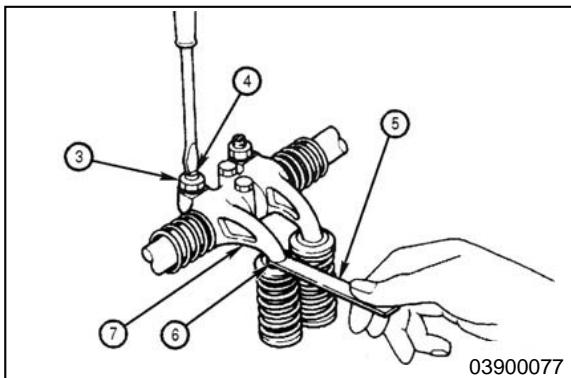
Check the bearings in the fan hub and other pulleys to make sure they are not causing excessive belt vibration and slippage.



Shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much airflow and the engine running cold.

Make sure that the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks.

Engine Compression

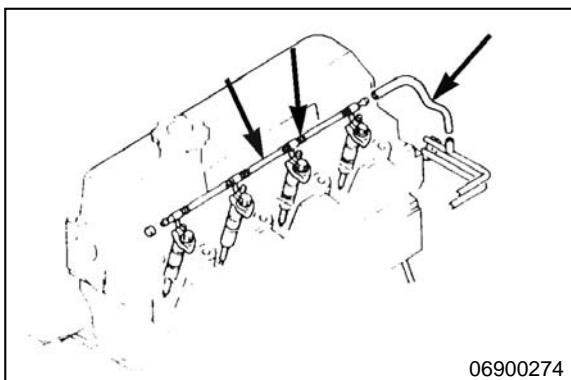


⚠️ WARNING

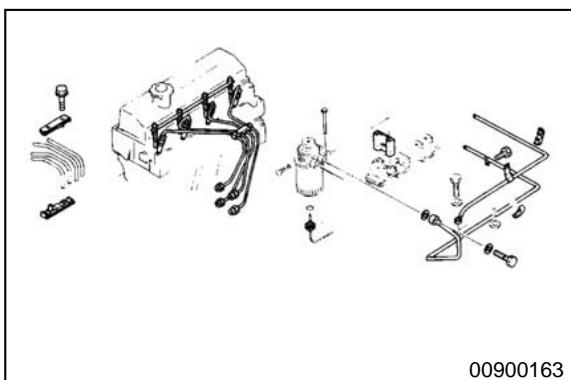
To reduce the possibility of personal injury, keep hands, long hair, jewelry, and loose fitting or torn clothing away from fans and other moving parts.

Measure the engine compression pressure while the engine is a minimum temperature of 50°C [122°F].

Adjust the overhead. Refer to Procedure 003-004.



Remove the fuel drain line.

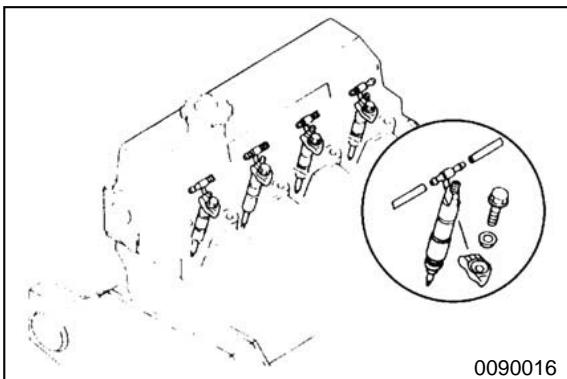


⚠️ WARNING

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

Remove the high-pressure fuel lines.

Disconnect the fuel shutoff valve.



⚠ WARNING



While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

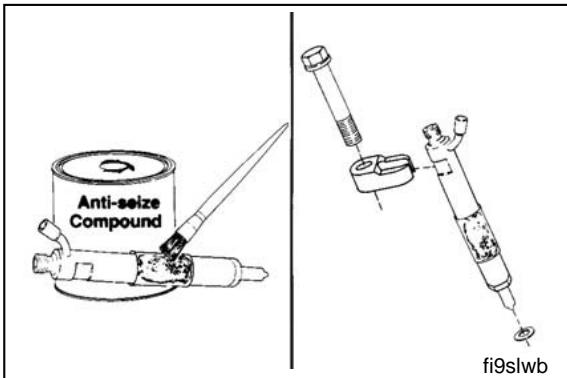
⚠ CAUTION



Do not allow dirt or debris to enter into the cylinder port. Debris and foreign objects in the cylinder can cause severe engine damage.

Remove the nozzle holder assembly for each cylinder.

Remove the injector for each cylinder.



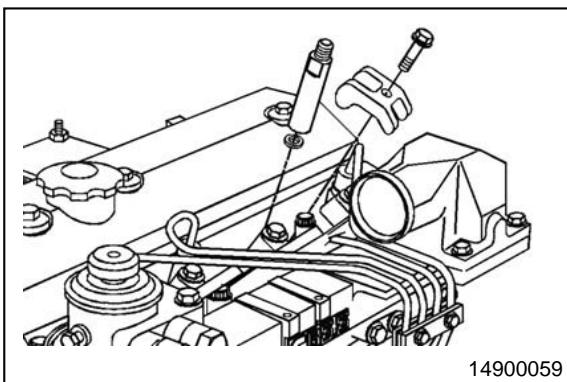
Lubricate the sealing lips of the sleeve with antiseize compound, Part Number 3824879, or equivalent.



Assemble the injector, sealing sleeve, a new copper washer (use only one washer), and the injector hold-down clamp.



A light coat of clean 15W-40 lubricating engine oil between the washer and the injector can help hold the washer in place during installation of the injector.

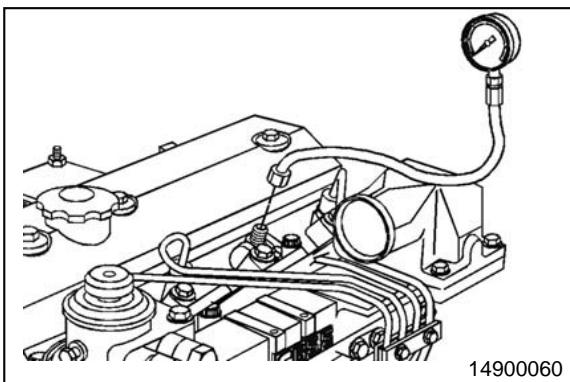


Install the compression adapter, Part Number 3164627, or equivalent, to the nozzle holder mounting section of the cylinder to be measured..



Tighten the compression adapter.

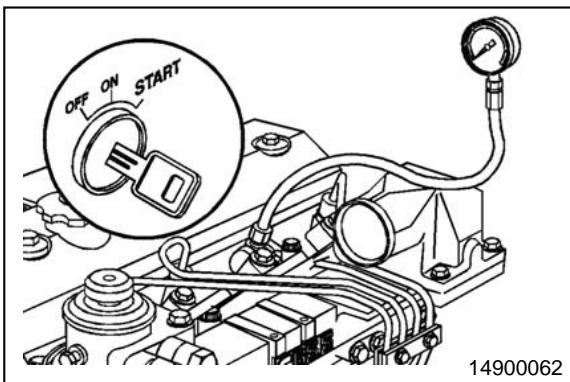
Torque Value: 44 n.m [33 ft-lb]



Most compression leakage can be prevented by applying a small amount of lubricating engine oil to the mounting section of the compression adapter.



Connect the compression gauge to the compression adapter.



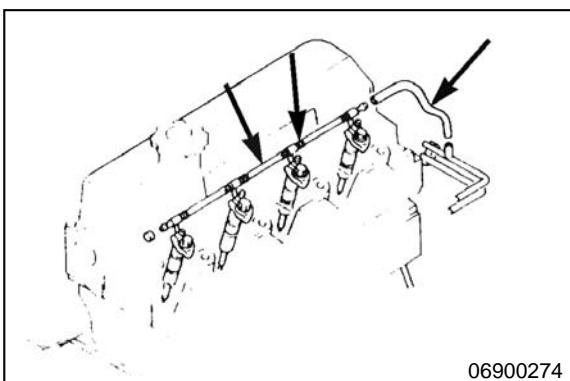
Start the engine.



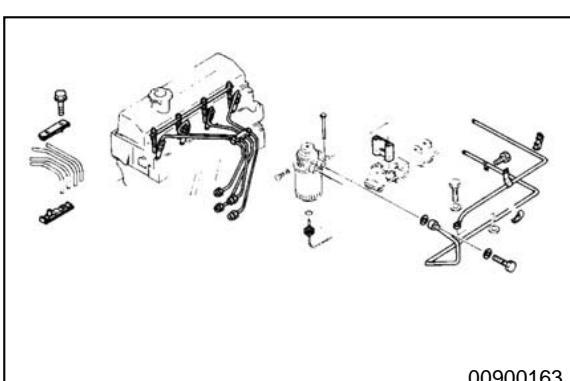
With the pointer on the gauge stabilized, check and read the gauge.

Engine Compression	
kPa	psi
2944	NOM
	427

Remove the compression gauge when test is complete.



Install the fuel drain line.



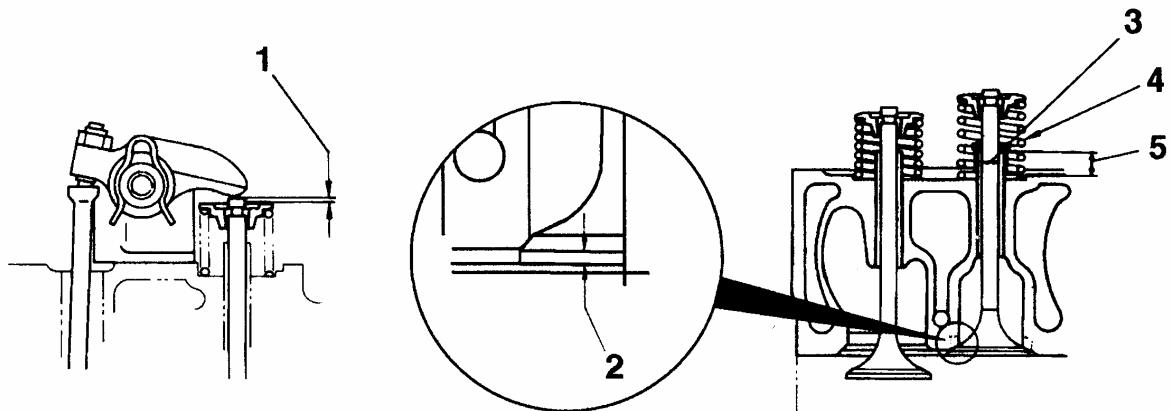
Install the high-pressure fuel lines.



Connect the fuel shutoff valve.

Specifications

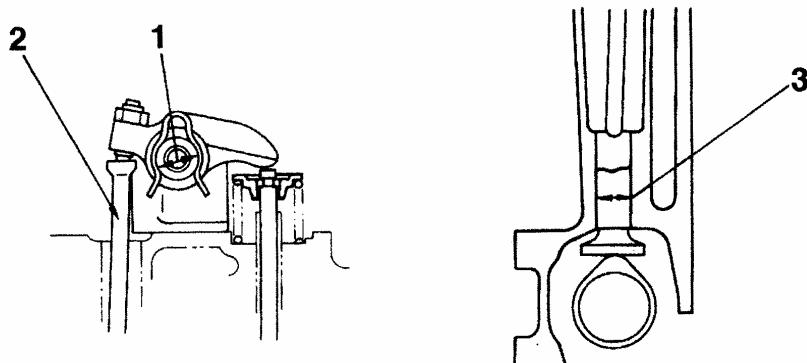
Valves, Valve Guides, and Springs



18900014

Ref	Inspection Item	Standard		Remarks
VALVES				
3	Stem Diameter	Intake	Nominal: 8 mm [0.3130 in]	Tolerance: -0.035 mm [-0.0014 in] -0.050 mm [-0.0020 in]
		Exhaust		
2	Clearance Between Guide and Stem	Intake	0.035 to 0.065 mm [0.0014 to 0.0026 in]	Clearance Limit: 0.20 mm [0.0079 in]
		Exhaust	0.050 to 0.080 mm [0.0020 to 0.0031 in]	
1	Head Thickness	Intake	1.40 to 1.60 mm [0.0551 to 0.0630 in]	Repair Limit: 1.00 mm [0.039 in]
		Exhaust		
5	Valve Clearance (at Cold and Warm)	Intake	0.35 mm [0.0138 in]	Tolerance: ±0.02 mm [±0.0008 in]
		Exhaust	0.50 mm [0.0197 in]	
VALVE GUIDE				
5	Protrusion Above Cylinder Head Surface	Intake	14.5 mm [0.571 in]	Tolerance: ±0.2 mm [±0.0079 in]
		Exhaust		
VALVE SPRING				
4	Free-Length		49.2 mm [1.94 in]	Repair Limit: 48.5 mm [1.90 in]
	Installed Length		40.5 mm [1.59 in]	—
	Installed Load		18.5 ±0.9 kg [40.8±2.0 lb]	Repair Limit: 16.5 kg [36.4 lb]
	Squareness		—	Repair Limit: 1.85

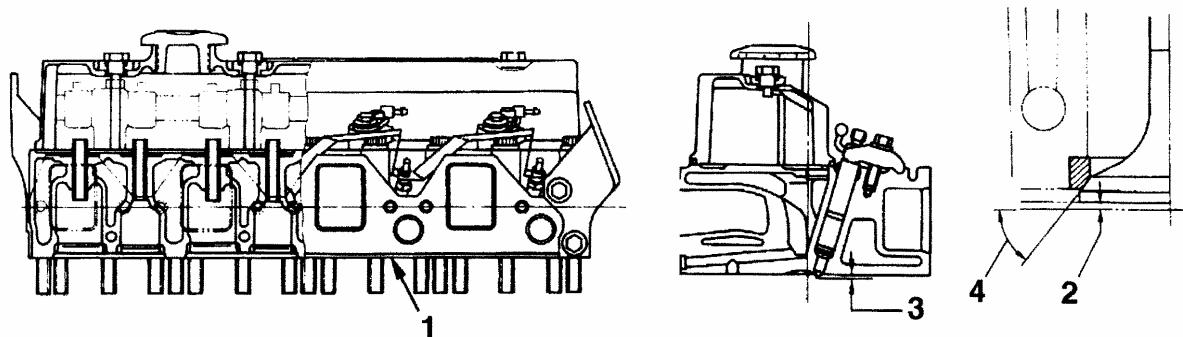
Rocker Arm Shaft, Push Rod and Tappets



18900016

Ref	Inspection Item	Standard	Remarks
VALVE ROCKER ARM SHAFT			
1	Diameter of Shaft	19 mm [0.75 in]	Tolerance: -0.020 mm [-0.0008 in]
	Diameter of Rocker Arm Shaft Hole	Nominal: 19 mm [0.75 in]	Tolerance: 0.030 mm [0.0012 in] 0.010 mm [0.0004 in]
	Clearance Between Rocker Arm and Shaft	0.010 to 0.050 mm [0.0004 to 0.0020 in]	Clearance Limit: 0.12 mm [0.0047 in]
	Bend of Shaft	—	Repair Limit: 0.20 mm [0.0079 in]
PUSH ROD			
2	Bend of Push Rod	—	Repair Limit: 0.30 mm [0.012 in]
TAPPET			
3	Clearance Between Tappet and Tappet Hole	0.012 to 0.048 mm [0.0005 to 0.0020 in]	Clearance Limit: 0.12 mm [0.0047 in]

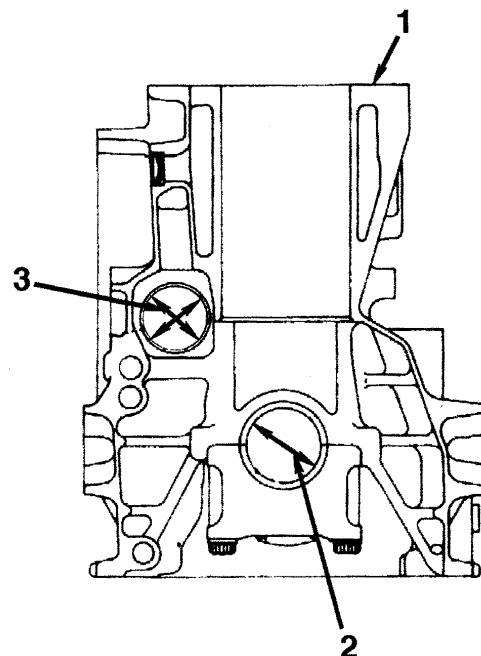
Cylinder Head



18900011

Ref	Inspection Item		Standard	Remarks	
CYLINDER HEAD					
1	Surface Flatness (Warpage Limit)		0.00 to 0.05 mm [0.00 to 0.002 in]	Repair Limit: 0.30 mm [0.012 in]	
2	Valve Seat	Intake	1.00 \pm 0.100 mm [0.039 \pm 0.004 in]	Repair Limit: 2.00 mm [0.079 in]	
		Exhaust	0.90 \pm 0.100 mm [0.035 \pm 0.004 in]	Repair Limit: 1.90 mm [0.075 in]	
3	Nozzle (Protrusion)		3.12 \pm 0.28 mm [0.123 \pm 0.011 in]	Tolerance: 2.700 to 3.500 mm [0.106 to 0.138 in]	
4	Valve Seat	Angle	45°	Tolerance: \pm 0°15'	Repair Limit: Judge condition of contact surface by vacuum test.

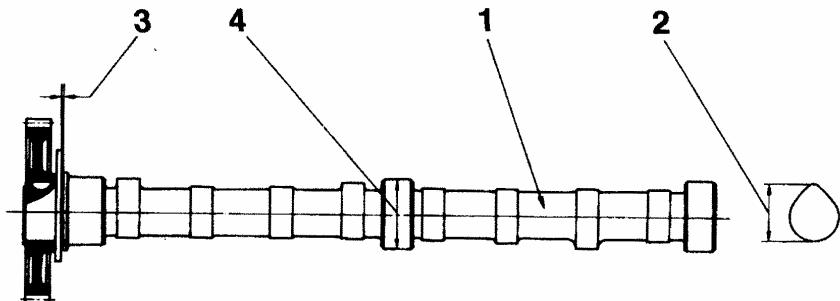
Cylinder Block



18900012

Ref	Inspection Item	Standard		Remarks
CYLINDER BLOCK				
1	Surface Flatness (Warpage Limit)	0.00 to 0.08 mm [0.00 to 0.003 in]		Repair Limit: 0.15 mm [0.006 in]
2	Inner Diameter of Main Bearing	STD	70.000 mm [2.756 in]	Repair Limit: 70.200 mm [2.764 in]
		U/S 0.25	69.750 mm [2.746 in]	Repair Limit: 69.950 mm [2.754 in]
		U/S 0.50	69.500 mm [2.736 in]	Repair Limit: 69.700 mm [2.744 in]
		U/S 0.75	69.250 mm [2.726 in]	Repair Limit: 69.450 mm [2.734 in]
		U/S 1.00	69.000 mm [2.717 in]	Repair Limit: 69.200 mm [2.724 in]
3	Inner Diameter of Cam Bushing	50.500 mm [1.988 in]		Repair Limit: 50.600 mm [1.992 in]

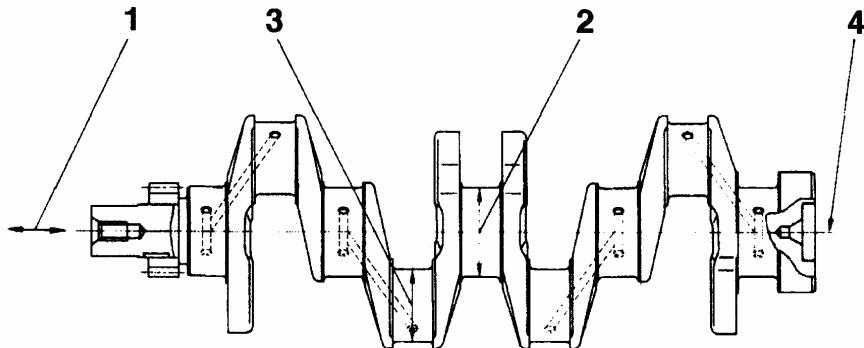
Camshaft and Camshaft Bushing



18900015

Ref	Inspection Item		Standard	Remarks
CAMSHAFT				
			Naturally Aspirated	Naturally Aspirated
1	Bend of Shaft		—	0.03 mm [0.0012 in]
2	Cam Height	Intake	42.69 mm [1.681 in]	Repair Limit: 42.20 mm [1.661 in]
		Exhaust	43.04 mm [1.694 in]	Repair Limit: 42.50 mm [1.673 in]
3	Thrust Clearance		0.150 to 0.350 mm [0.0059 to 0.0138 in]	Repair Limit: 0.50 mm [0.0197 in]
CAMSHAFT BUSHING				
4	Clearance to Cam	No. 1 No. 2 No. 3	0.040 to 0.140 mm [0.0016 to 0.0055 in]	Repair Limit: 0.25 mm [0.0098 in]

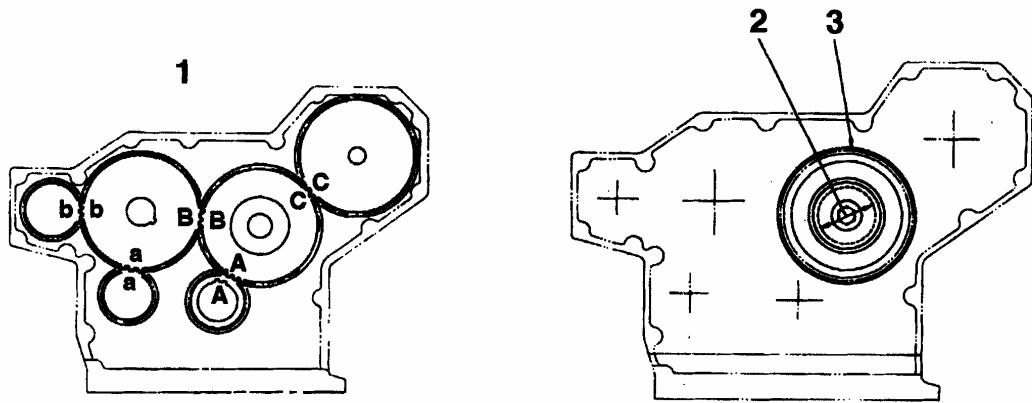
Crankshaft



18900019

Ref	Inspection Item	Standard	Remarks
CRANKSHAFT			
1	Thrust Clearance	0.131 to 0.351 mm [0.0052 to 0.0138 in]	Repair Limit: 0.40 mm [0.016 in]
2	Main Journal	STD	70.000 mm [2.756 in]
		U/S 0.25	69.75 mm [2.746 in]
		U/S 0.50	69.50 mm [2.736 in]
		U/S 0.75	69.25 mm [2.726 in]
		U/S 1.00	69.00 mm [2.717 in]
3	Roundness	—	Repair Limit: 0.020 mm [0.0008 in]
	Clearance	0.043 to 0.103 mm [0.0017 to 0.0041 in]	Clearance Limit: 0.25 mm [0.0098 in]
4	Crank Pin Journal	STD	57.000 mm [2.244 in]
		U/S 0.25	56.750 mm [2.234 in]
		U/S 0.50	56.500 mm [2.224 in]
		U/S 0.75	56.250 mm [2.215 in]
		U/S 1.00	56.000 mm [2.205 in]
5	Roundness	—	Repair Limit: 0.020 mm [0.0008 in]
	Clearance of Crank Pin Journal	0.029 to 0.089 mm [0.0011 to 0.0035 in]	Clearance Limit: 0.22 mm [0.0087 in]
6	Bend of Crankshaft	—	Repair Limit: 0.09 mm [0.0035 in]

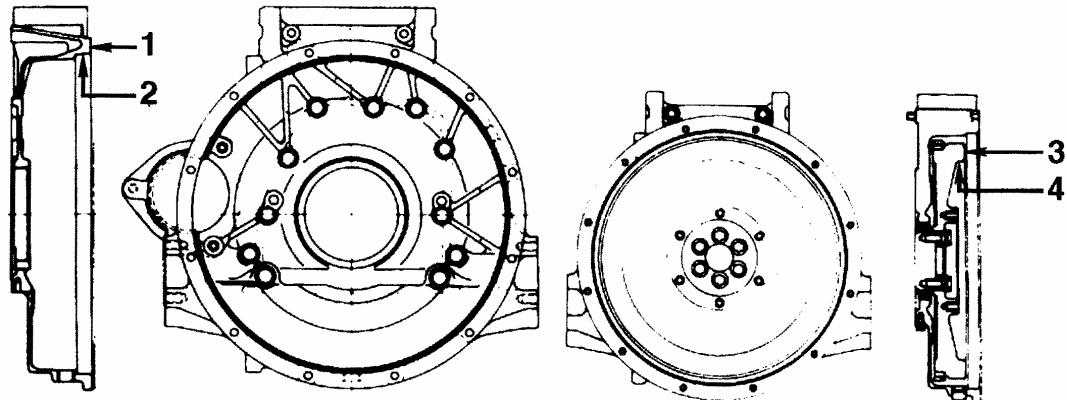
Timing Gear



18900018

Ref	Inspection Item	Standard	Remarks		
TIMING GEAR					
1	Bend of Shaft	A	Crankshaft gear and idler gear	Naturally Aspirated	Replacement Limit: 0.40 mm [0.0157 in]
		B	Camshaft gear and idler gear	0.08 mm to 0.19 mm [0.0031 in to 0.007 in]	
		C	Injection pump gear and idler gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
		a	Camshaft gear and oil pump gear	0.07 mm to 0.29 mm [0.003 in to 0.011 in]	
		b	Camshaft gear and PTO gear	0.15 mm to 0.30 mm [0.006 in to 0.012 in]	
2	Clearance Between Bushing and Shaft		0.015 mm to 0.050 mm [0.0006 in to 0.002 in]	Replacement Limit: 0.10 mm [0.0039 in]	
3	End Play of Idler Gear		0.03 mm to 0.09 mm [0.0012 in to 0.0035 in]	Replacement Limit: 0.20 mm [0.0079 in]	

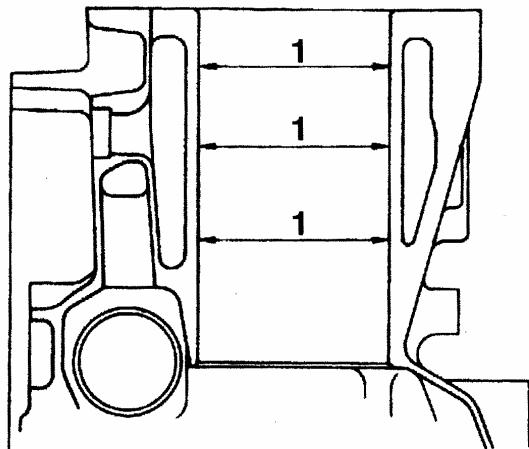
Flywheel



18900013

Ref	Inspection Item	Standard	Remarks
FLYWHEEL			
1	Face Runout of Flywheel Housing	—	Repair Limit: 0.30 mm [0.012 in]
2	Radial Runout of Flywheel Housing	—	Repair Limit: 0.35 mm [0.014 in]
3	Face Runout of Flywheel	—	Repair Limit: 0.15 mm [0.0059 in]
4	Radial Runout of Flywheel	—	Repair Limit: 0.20 mm [0.079 in]

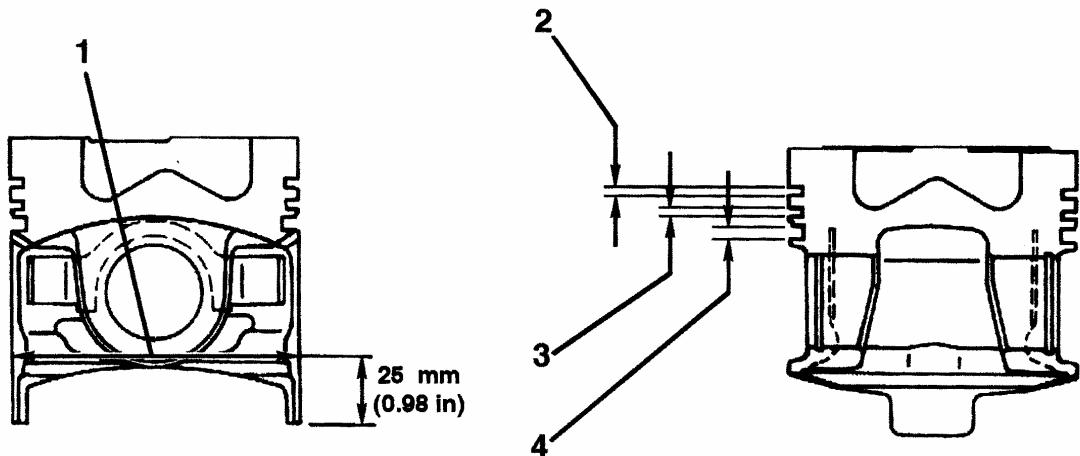
Cylinder



18900020

Ref	Inspection Item	Standard		Remarks	
CYLINDER					
1	Bore	STD	ID: 95.00 mm [3.740 in]	Tolerance: 0.022 mm [0.0008 in]	Repair Limit: ID: 95.15 mm [3.746 in]
	Roundness of Cylinder		—		Repair Limit: 0.02 mm [0.0008 in]
	Cylindricity of Cylinder		—		

Piston

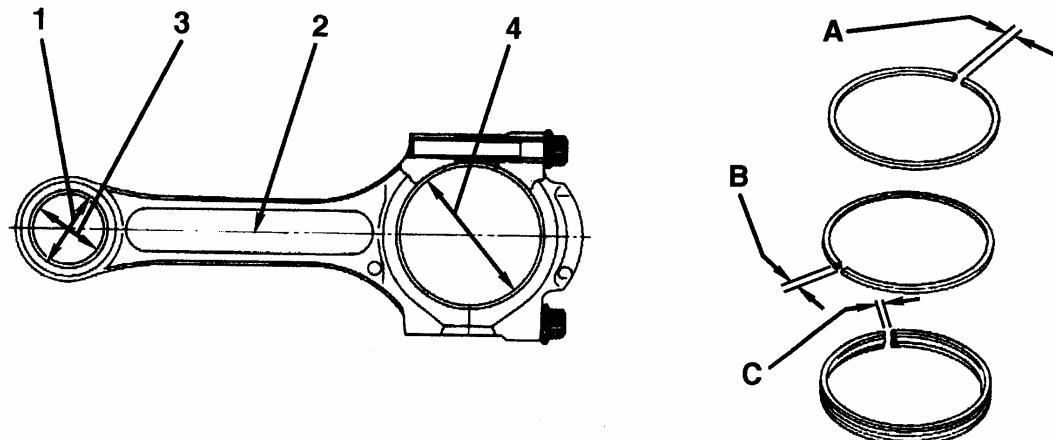


18900020

Ref	Inspection Item	Standard		Remarks
PISTON				
1	Diameter	STD	ID: 95.00 mm [3.740 in]	Repair Limit: ID: 94.85 mm [3.734 in]
2		Top	0.06 to 0.10 mm [0.0024 to 0.0039 in]	2.0 mm [0.079 in]*
3	Clearance Between Piston Ring Groove and Piston Ring	Second	0.03 to 0.07 mm [0.0012 to 0.0028 in]	2.0 mm [0.079 in]*
		Oil	4.0 mm [0.158 in]*	Repair Limit: 0.20 mm [0.0079 in]
				Repair Limit: 0.15 mm [0.0059 in]

*Width of Groove (Nominal)

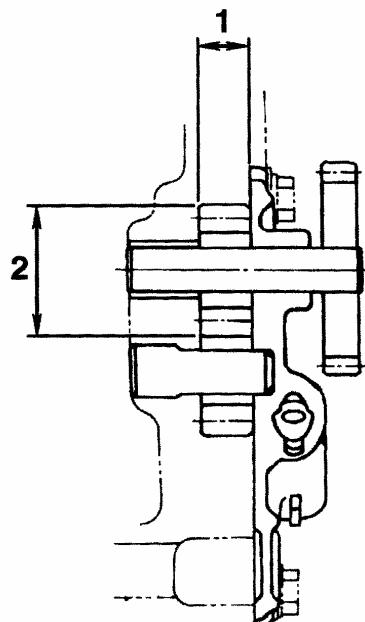
Connecting Rod, Piston Ring and Piston Pin



18900022

Ref	Inspection Item	Standard		Remarks
PISTON PIN				
1	Outer Diameter	Nominal OD: 30.00 mm [1.181 in]		—
	Clearance	0.004 to 0.018 mm [0.0002 to 0.0007 in]		Clearance Limit: 0.05 mm [0.002 in]
PISTON RING				
A	Piston Ring Gap	Top	0.30 to 0.45 mm [0.012 to 0.018 in]	Clearance Limit: 2.00 mm [0.079 in]
B		Second	0.30 to 0.45 mm [0.012 to 0.018 in]	Clearance Limit: 2.00 mm [0.079 in]
C		Oil	0.25 to 0.45 mm [0.0098 to 0.018 in]	Clearance Limit: 1.50 mm [0.059 in]
CONNECTING ROD				
2	Bend (B)/Torsion (T)	Maximum: 0.20/0.30 mm [0.0078/0.0118 in]		Repair Limit: 0.25/0.35 mm [0.0098/0.0138 in]
3	Inner Diameter of Bushing Hole	33.00 mm [1.299 in]		Tolerance: 0.025 mm [0.001 in]
CONNECTING ROD BUSHING				
1	Clearance Between Bushing and Piston Ring (Small End)	0.020 to 0.039 mm [0.0008 to 0.0015 in]	Nominal OD: 30.00 mm [1.18 in]	Clearance Limit: 0.100 mm [0.0039 in]
CONNECTING ROD BEARING				
4	Inner Diameter	STD	57.00 mm [2.244 in]	Repair Limit: 57.20 mm [2.252 in]

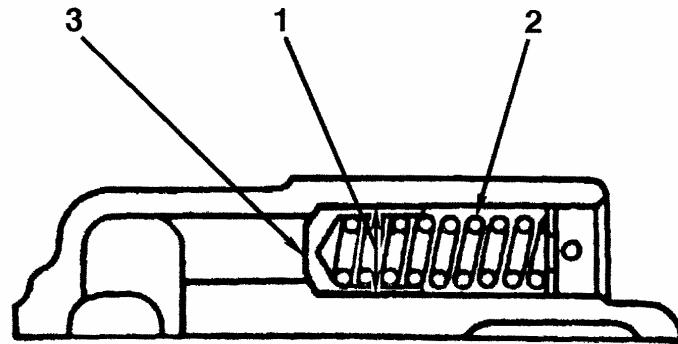
Oil Pump



18900017

Ref	Inspection Item		Standard	Remarks
1	Clearance of Pump Gear	Axial	0.030 to 0.085 mm [0.0012 to 0.0033 in]	Clearance Limit: 0.10 mm [0.0039 in]
2		Radial	0.045 to 0.090 mm [0.0018 to 0.0035 in]	Clearance Limit: 0.13 mm [0.0051 in]

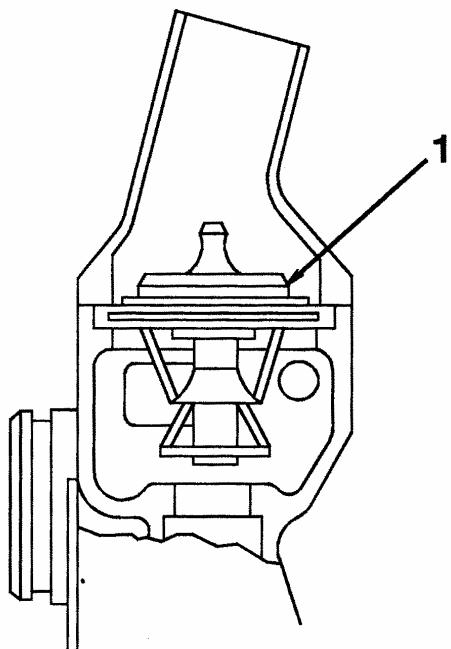
Regulator Valve



18900023

Ref	Inspection Item	Standard					Remarks
		Standard Size	Tolerance		Standard Clearance	Clearance Limit	
1	Clearance Between Valve and Body		Shaft	Hole		Replace	
	11 mm [0.43 in]	-0.050mm -0.077mm [0.002 in] [0.003 in]	0.020 mm -0.020mm [0.0008 in] [0.0008 in]	0.030 to 0.097 mm [0.001 to 0.004 in]			
	Standard		Repair Limit				
		Free-Length	Installed Length	Installed Load	Free-Length		Installed Load
2	Regulator Valve Spring Naturally Aspirated	33.1 mm [1.30 in]	27.8 mm [1.09 in]	2.44 kg [5.38 lb]	—	2.30 kg [5.07 lb]	Repair or Replace Spring
3	Regulator Valve Set Pressure	Standard: $5.0 \pm 0.5 \text{ kg/cm}$					

Thermostat



18900024

Ref	Inspection Item	Standard	Remarks
THERMOSTAT			
1	Thermostat	<p>Cracking Temperature: 82° C \pm2° C [180° F \pm2° F]</p> <p>Fully Open Temperature: 95° C [203° F]</p> <p>Fully Open Lift: Minimum: 8 mm [0.315 in] (when immersed in a hot water bath at 95° C [203° F] for 4 to 5 minutes)</p>	<p>(Fully Open: Shall open fully when immersed in hot water bath at a temperature between 77° C [171° F] and 95° C [203° F] for 4 to 5 minutes)</p> <p>Replace</p>

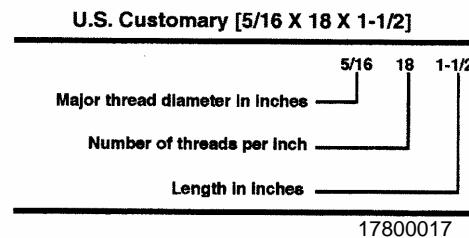
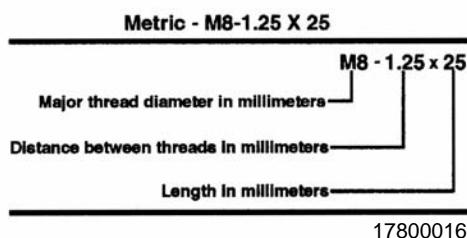
Capscrew Markings and Torque Values

! CAUTION

When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:



NOTE:

1. **Always** use the torque values listed in the following tables when specific torque values are not available.
2. Do **not** use the torque values in place of those specified in other sections of this manual.
3. The torque values in the table are based on the use of lubricated threads.
4. When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric

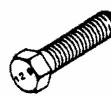
Commercial Steel Class

8.8

10.9

12.9

Capscrew Head Markings



Body Size	Torque				Torque				Torque				
	Diameter	Cast Iron		Aluminum		Cast Iron		Aluminum		Cast Iron		Aluminum	
mm		N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
6		9	5	7	4	13	10	7	4	14	9	7	4
7		14	9	11	7	18	14	11	7	23	18	11	7
8		23	17	18	14	33	25	18	14	40	49	18	14
10		45	33	30	25	65	50	30	25	70	50	30	25
12		80	60	55	40	115	85	55	40	125	95	55	40
14		125	90	90	65	180	133	90	65	195	145	90	65
16		195	140	140	100	280	200	140	100	290	210	140	100
18		280	200	180	135	390	285	180	135	400	290	180	135
20		400	290	-	-	550	400	-	-	-	-	-	-

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number	5	8
Capscrew Head Markings		
These are all SAE Grade 5 (3 line)		
	Capscrew Torque - Grade 5 Capscrew	Capscrew Torque - Grade 8 Capscrew

Capscrew Body Size	Cast Iron		Aluminum		Cast Iron		Aluminum	
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
- 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
- 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
- 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
- 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
- 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
- 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
- 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
- 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
- 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
- 14	800	590	650	480	1200	890	650	480

Fraction, Decimal, Millimeter Conversions

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversion Chart

N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
1	8.850756 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
1	0.737562 ft-lb	90	66	190	140
12	9	95	70	195	144
14	10	100	74	200	148
15	11	105	77	205	151
16	12	110	81	210	155
18	13	115	85	215	159
20	15	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184

NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.

Pipe Plug Torque Values

Thread in	Actual Thread O.D. in	Torque		Torque	
		N·m	ft-lb	N·m	ft-lb
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

Tap-Drill Chart - U.S. Customary and Metric

NOTE ON SELECTING TAP-DRILL SIZE: The tap drill size shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

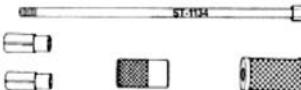
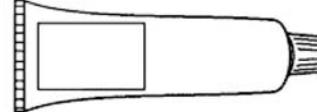
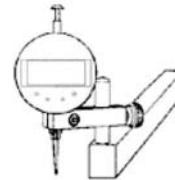
Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size
60%	75%		60%	75%		60%	75%		60%	75%	
		48 1.96mm 5/64		12-24 47 2.00mm M5.5x.9	4.40mm 16 4.50mm 15			7.50mm 19/64 7.60mm N		13.25mm 5/8-11 M15x1.5	
3-48		M2.5x.45 2.05mm	12-24	12-28 45 2.10mm M6.5x.9	4.60mm 14 4.70mm 13		M9x1.25	7.70mm 7.75mm 7.80mm 7.90mm 5/16	13.75mm 35/64 M16x2		
3-48	3056	M2.6x.45 2.15mm	12-28		4.75mm 3/16			8.00mm M9x1	14.00mm M18x2 5/8-18	9/16 M16x1.5	14.25mm
3-56	4-36	44 2.20mm M2.6x.45			4.80mm 11 4.90mm 10			8.10mm M8x1	14.50mm 37/64		14.75mm
4-36	4-40	43 2.25mm M2.6x.45			9 42 3/32 M3x.6	5.00mm 8 5.10mm 7	3/8-16 1/8-27NPT	8.20mm P 8.25mm 8.30mm 8.40mm Q	15.00mm M18x1.5 M17x1.5	19.32 M18x2.5	15.25mm
4-40	4-48	40 2.30mm M3x.6			13/64 40 5.20mm 39	5.10mm 5 5.25mm 5.30mm 4	1/8-27NPT	8.50mm M10x1.5 M10x1.25	15.50mm M18x2.5 M18x2 M10x1.5	21/32 M19x2.5	15.75mm
M3x.6	M3x.5	2.50mm 38 5-40	M6x1		5.40mm 3 5.50mm 7/64	5.40mm 3 5.50mm 7/32	3/8-24 1/8-27NPT	8.60mm M10x1.5 M10x1	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	21/64 M18x1.5 M17x1.5 M18x2.5	5/8
M3x.5	5-44	2.60mm 37 5-44		1/4-20 M6x.75	5.60mm 2 5.70mm 5.75mm 1	5.60mm 2 5.70mm 5.75mm 1	3/8-24 1/8-27NPT	8.70mm M10x1.5 M10x1.25	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/32 M18x1.5 M17x1.5 M18x2.5	17.00mm
5-44	6-32	36 2.75mm 7/64		1/4-28	5.80mm 3 5.90mm 35 2.80mm 34 33 2.90mm 32 3.00mm 31 3.10mm 1/8	5.80mm 3 5.90mm 5.60mm 2 5.70mm 5.75mm 1	3/8-24 1/8-27NPT	8.80mm M10x1.5 M10x1	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/32 M18x1.5 M17x1.5 M18x2.5	43/64
6-32	6-40	M3.5x8 2.90mm			5.80mm 3 5.90mm A 15/64	5.80mm 3 5.90mm A	3/8-24 1/8-27NPT	8.90mm M11x1.5 M11x1.5	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/16 M20x2.5	17.25mm
M3.5x6	M3.5x6	3.00mm 31 3.10mm 3.20mm 3.25mm 30 3.30mm 3.40mm 3.50mm 29 3.50mm 3-36			5.90mm B 6.00mm 6.10mm C 6.20mm D 6.25mm E 6.40mm F 6.50mm G 6.60mm H 6.80mm I 7.00mm J 7.10mm K 9/32 L 7.40mm M	5.90mm B 6.00mm 6.10mm C 6.20mm D 6.25mm E 6.40mm F 6.50mm G 6.60mm H 6.80mm I 7.00mm J 7.10mm K 9/32 L 7.40mm M	7/16-14 M10x1	9.00mm M11x1.5	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/16 M20x2.5	17.50mm
M4x.75	M4x.75	3.40mm 3.50mm 29 3.50mm 3-36	M7x1		9.10mm 23/64	9.10mm 23/64	3/4-16	9.40mm M11x1.5	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/16 M20x2.5	45/64
M4x.75	M4x.7	3.40mm 3.50mm 29 3.50mm 3-36		1/4-18	9.20mm 9.30mm U	9.20mm 9.30mm U	7/16-14 M10x1	9.40mm M11x1.5	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/16 M20x2.5	23/32
M4x.75	M4x.7	3.40mm 3.50mm 29 3.50mm 3-36	M7x1		9.50mm 3/8 V	9.50mm 3/8 V	3/4-16	9.40mm M11x1.5	15.75mm M19x2.5 M18x2.5 M18x2 M10x1	11/16 M20x2.5	47/64
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36			9.60mm 7/8-9	9.60mm 7/8-9	7/8-9	9.70mm M22x2.5	18.00mm M22x2.5	18.50mm	19.00mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36	M7x.75		9.75mm M22x2.5	9.75mm M22x2.5	7/8-9	9.80mm M22x2.5	18.50mm	19.25mm	19.50mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36			9.80mm M22x2.5	9.80mm M22x2.5	7/8-9	9.90mm M22x2.5	19.25mm	19.50mm	19.75mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36	M7x.75		9.90mm M22x2.5	9.90mm M22x2.5	7/8-9	10.00mm M22x2.5	20.00mm	20.25mm	20.50mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36			10.20mm X	10.20mm X	7/8-14	10.30mm M22x2.5	20.50mm	20.75mm	21/16
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36	M7x.75		13/32 Y	13/32 Y	7/8-14	10.40mm M22x2.5	21.00mm	21.25mm	53/64
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36			Z	Z	M24x3	10.50mm M22x2.5	21.50mm	21.75mm	21/25mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36	M6x1.25		14-18NPT	14-18NPT		10.50mm M12x1.5	10.50mm M12x1.5	21.75mm	22/25mm
M4x.75	M4.5x.75	3.40mm 3.50mm 29 3.50mm 3-36			11.25mm 11.50mm 29/64	11.25mm 11.50mm 29/64	M24x2	11.25mm M24x2	22.00mm	22.25mm	22.50mm
10-24	M5x1	4.00mm 22 5/32	M6x1.25		11.50mm 29/64	11.50mm 29/64	1-8	11.75mm M24x1.5	22.25mm	22.50mm	22.75mm
10-24	M5x1	4.00mm 22 5/32			11.75mm 11.50mm 1/2-13	11.75mm 11.50mm 1/2-13	1-8	11.75mm M24x1.5	22.50mm	22.75mm	23/32
10-32	M5x.8	4.20mm 20 21			12.00mm 12.25mm 31/64	12.00mm 12.25mm 31/64	M25x2	12.00mm M25x2	23.00mm	23.25mm	23/32
10-32	M5x.8	4.20mm 20 21	M6x1		12.50mm 13.00mm 1/2	12.50mm 13.00mm 1/2	1-12	12.50mm M25x1.5	23.50mm	23.75mm	23/32
M6x1	M5x.9	4.10mm 19 4.25mm 18			12.75mm 13.00mm 33/64	12.75mm 13.00mm 33/64	M20x1.5	12.75mm M20x1.5	23.75mm	24/32	15/16
10-32	M5x.9	4.10mm 19 4.25mm 18	M6x1.25		13.00mm 33/64	13.00mm 33/64					
M6x.8	M5x.8	4.20mm 17 11/64									

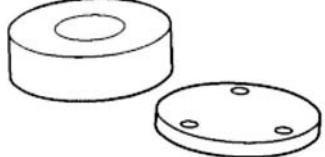
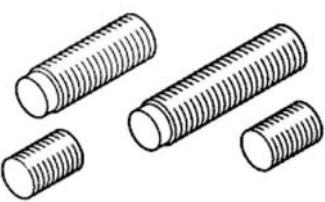
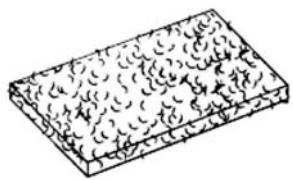
17800013

Weight and Measures - Conversion Factors

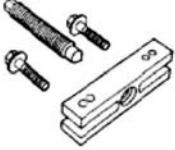
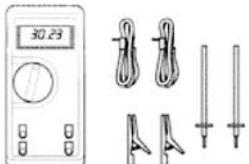
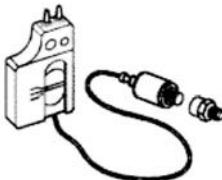
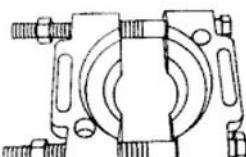
Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbr.		
Area	sq. inch	in ²	sq. millimeters	mm ²	645.16	0.001550
			sq. centimeters	cm ²	6.452	0.155
	sq. foot	ft ²	sq. meter	m ²	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H ₂ O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H ₂ O	Millimeters of water	mm H ₂ O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32)÷1.8	(1.8x°C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in ³	liter	l	0.01639	61.02545
	cubic inch	in ³	cubic centimeter	cm ³	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

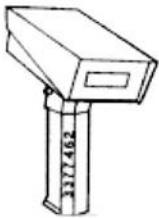
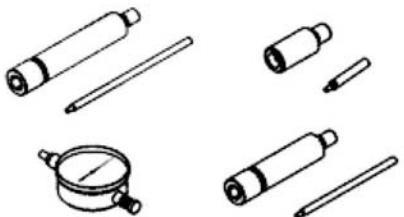
Special Tools

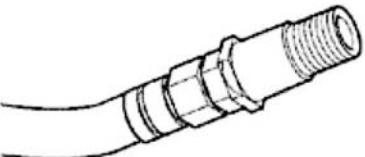
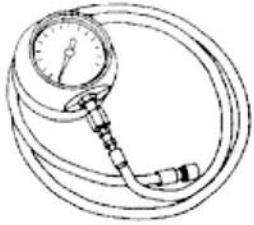
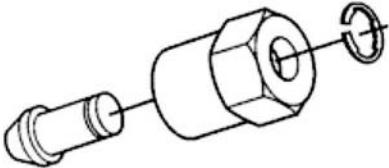
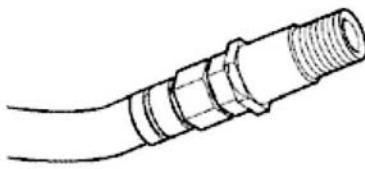
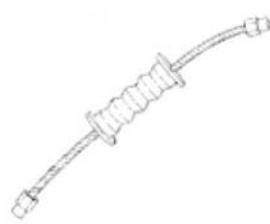
Style	Tool No.	Tool name
	ST 647	Standard Puller
	3163086	Lubriplate™ Multi-Purpose Lubricant
	3163720	Dowel Pin Extractor
	3164067	Silicone Sealant
	3164438	Depth Gauge Assembly

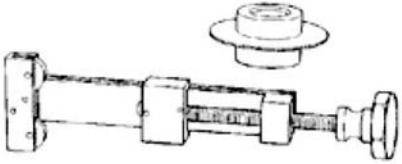
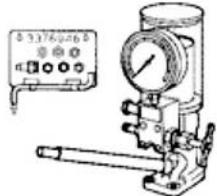
Style	Tool No.	Tool name
 A line drawing of two circular tools. The top one is a thick, flat cylinder with a central hole. The bottom one is a thinner, flatter disc with two small holes on its side.	3164900	Crankshaft Seal Installer
 A line drawing of a tube of sealant with a screw-on cap. The tube is tapered at the bottom and has a small 'G' logo on the side.	3375066	Sealant
 A line drawing of a small bottle of sealant with a screw-on cap. The bottle is tapered at the bottom and has a small 'G' logo on the side.	3375068	Sealant
 A line drawing of four threaded metal inserts. They are cylindrical with a flared, threaded base and a smooth top.	3822709	Thread Repair Inserts
 A line drawing of a rectangular abrasive pad. It has a textured, granular surface and a thin, dark border.	3823258	Abrasive Pad

Style	Tool No.	Tool name
	3823942	Small Bushing Driver Set
	4918219	Precision Straightedge
	3822509	Injector Bore Brush
	3824379	Antiseize Lubricant
	4918219\	Precision Straightedge

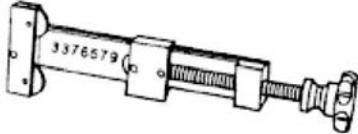
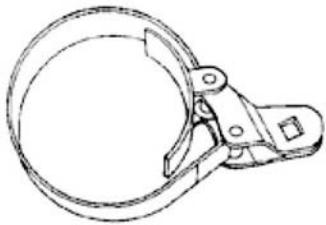
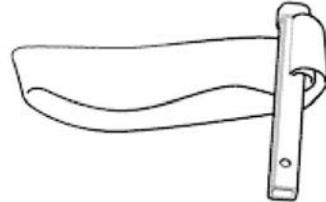
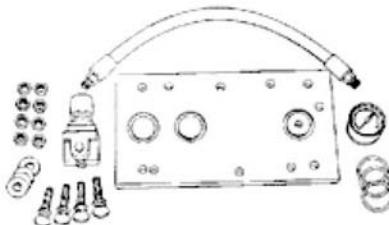
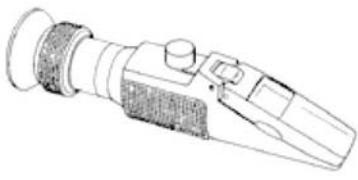
Style	Tool No.	Tool name
	ST 647	Standard Puller
	3164488	Digital Multimeter
	3164489	Digital Multimeter
	3164491	Pressure/Vacuum Module
	3375326	Bearing Separator Tool

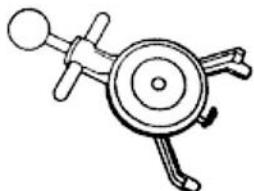
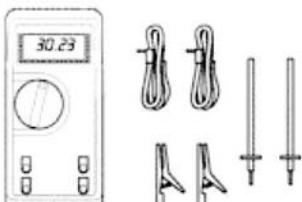
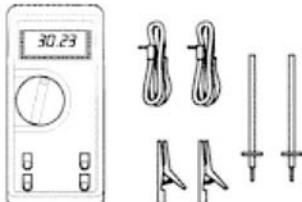
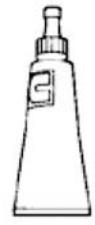
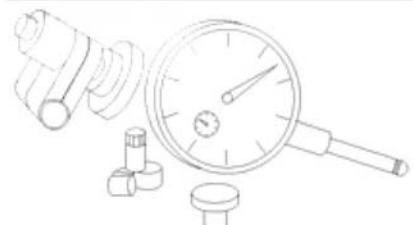
Style	Tool No.	Tool name
	3377462	Digital Optical Tachometer
	3823705	Graduated Beaker
	3824510	QD Contact Cleaner
	4918193	Injection Timing Gauge Kit
	4818677	Fuel Pump Drive Gear Retention Tool

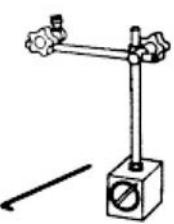
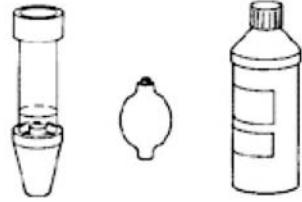
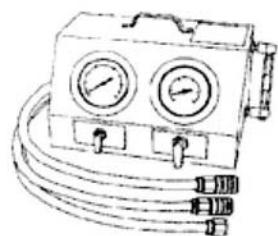
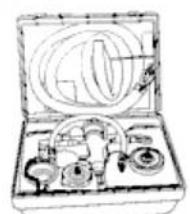
Style	Tool No.	Tool name
	4918679	Fuel Return Flow Hose (Fuel Pump)
	ST 1273	Pressure Gauge
	3164325	Fuel System Leak Tester
	3164617	Fuel Return Flow Hose (fuel rail pressure relief valve)
	3164706	Injector Remover

Style	Tool No.	Tool name
	3376579	Filter Cutter
	3376946	Injection Nozzle Tester
	3376947	Injector Nozzle Cleaning Kit
	3400157	Fuel Filter Wrench
	3823705	Graduated Beaker

Style	Tool No.	Tool name
	3824879	Antiseize Lubricant
	3163338	Black Light Lamp
	3164067	Silicone Sealant
	3164491	Pressure/Vacuum Module
	3375273	Pressure Gauge Kit

Style	Tool No.	Tool name
	3376579	Tube (Filter) Cutter
	3400157	Oil Filter Wrench
	3400158	Oil Filter Wrench
	3823876	Lubricating Oil Cooler Test Kit
	CC-2800	Refractometer

Style	Tool No.	Tool name
	ST-1138	Belt Tension Gauge
	3164488	Digital Multimeter
	3164489	Digital Multimeter
	3375066	Sealant
	3376050	Dial Indicator Assembly

Style	Tool No.	Tool name
	3377399	Magnetic Base Indicator Holder
	3822524	Belt Tension Gauge
	3822985	Combustion Leak Test Kit
	3822994	Engine Coolant Analyzer
	3824319	Coolant Dam/Pressure Tester